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A REVIEW OF METHODS FOR ESTIMATING CARBON SEQUESTRATION AT INTENSIVE GREEN ROOFS

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ABSTRACT

In addition to providing space for residents, intensive green roofs or rooftop gardens enhance a building's aesthetic value and contribute towards its environmental performance. To deal with excessive carbon dioxide emissions, intensive green roofs have the potential to contribute through a carbon sequestration strategy with plants as one of its key components. The estimation of the carbon sequestered amount is significant, because it will be used as a benchmark to assess and optimize the potential of intensive green roofs for carbon sequestration. Researchers have used various methods to estimate the amount of carbon sequestration required whether it involves a single tree, plantation, forest, urban forest, or urban landscape. However, the methods used to estimate carbon sequestration has received relatively less attention from local researchers. Therefore, this review paper assesses the methods used for estimating carbon sequestration that can be adopted. A review of the literature on carbon sequestration estimation methods showed that the MyCREST carbon sequestration calculator is the most suitable method for estimating carbon sequestration due to its unique conditions for intensive green roofs.

1.0 INTRODUCTION

In addition to providing space for residents, intensive green roofs or rooftop gardens enhance a building's aesthetic value and contributes to a building's environmental performance. Basically, green roofs can be categorized as extensive or intensive (Townshend & Duggie, 2007; Nagase & Dunnett, 2010). An extensive green roof consists of moss, sedum herbs, and grasses, while an intensive green roof consists of a lawn, perennials, shrubs, and trees. To deal with excessive carbon dioxide (CO_2) emissions, intensive green roofs have the potential to contribute through a carbon sequestration strategy with plants as one of its key components. Green roofs are among the green features that can improve building environmental performance through the cooling potential/thermal performance/heat reduction (Ismail, 2009; Ahmad, Hashim, & Jani, 2011; Ahmed & Rumana Rashid, 2009; Kamarulzaman *et al.*, 2014), storm water management; (Ahmad *et al.*, 2011; Sultana *et al.*, 2015), and carbon uptake/carbon sequestration (Ismail *et al.*, 2012).

A green roof is a part of building facilities, which is specifically designed to counterbalance CO_2 emissions. Assessing the performance of green roofs is vital for developing potential strategies to reduce CO_2 emissions. Therefore, estimating the amount of carbon sequestration is useful and sets a baseline for optimizing their performance. However, the methods for estimating carbon sequestration on green roofs are less researched because of the unique conditions prevalent with intensive green roofs, which consist of various plant species planted on man-made structures. The methods for estimating carbon sequestration were established specifically for forests, urban forests, and plantations. By reviewing the methods adopted by previous researchers will help to better assess carbon sequestration performance for intensive green roofs. Therefore, this paper assesses the methods used for estimating carbon sequestration, which can be adopted for carbon sequestration estimation.

2.0 METHODS

This paper presents the literature on green roof carbon sequestration and methods for estimating carbon sequestration. The objective of this literature review is to discuss methods for estimating carbon sequestration for green roofs. First, we provide an overview of tree carbon sequestrations and methods to estimate carbon sequestration. Further, we analyzed as well as propose suitable methods to estimate carbon sequestration. An extensive literature review from 2004–2018. The notable findings of previous studies used as for principles required for carbon sequestration estimation are acknowledged and included.

This literature reviews begins with materials collected from searching ISI Web of Science, Universiti Teknologi Malaysia databases, Science Direct, Scopus, and related websites using keywords as follows: green roofs carbon sequestration, carbon sequestration calculator, estimation method, intensive green roofs, and green roofs performance. Only 22 articles specifically related to green roof carbon sequestration were located. Owing to the limited number of papers for carbon sequestration estimation methods for green roofs, we included urban tree estimation methods. The review commences in Section 3 and embraces methods for estimating carbon sequestration. Section 4 covers the analysis and discussion on literature the findings. Lastly, Section 5 is our conclusions.

3.0 LITERATURE REVIEW

3.1 Methods for estimating carbon sequestration

In assessing carbon sequestration performance for intensive green roofs, estimating tree carbon sequestration is fundamental. Several methods are used for estimating the amount of carbon sequestration by trees. The method used depends on the type of data required, i.e. the time, costs, and areas of survey. Basically, in estimating carbon sequestration, tree biomasses must be estimated. The tree biomass can be classified into two categories: above-ground and below-ground. Above-ground biomass comprises three components such as stems, branches, and foliage; whereas below-ground biomass comprises all live roots (Mitra, Sengupta, & Banerjee, 2011). The importance of tree biomasses rely on the a rule that 50% of above-ground biomass consists of carbon (Aguaron & McPherson, 2012; Basuki *et al.*, 2009); then, the estimation of carbon sequestration and carbon stock can be made.

In estimating tree biomass, two methods used are destructive sampling and non-destructive sampling. Both methods can be performed through in situ sampling. Destructive sampling is the most accurate method for estimating tree biomasses. The destructive sampling method was performed to construct an allometric equation and validation (Basuki *et al.*, 2009). The process measures the weight of a tree by cutting the tree into components such as tree trunk, leaf, and branch; drying in an oven; and, then, weighing each part to identify its carbon content (Breu, Guggenbichler, & Wollmann, 2012). However, this method contributes to the destruction of trees (Basuki *et al.*, 2009), and is tedious, expensive, consumes resources, and requires time (Ebuy *et al.*, 2011). Additionally, this method is not suitable for a large area and tree sample size, or endangered tree species (Vashum, Jayakumar, & Vashum, 2012). Conversely, the non-destructive sampling method estimates the tree biomass without chopping trees down. This method is pertinent when a species is not practicable or feasible for harvest such as rare or endangered tree species (Vashum *et al*., 2012). Various parts of the trees are measured as follows: height, volume, and wood density; and, then, by using the allometric equation, the biomass will be calculated (Vashum *et al*., 2012). The allometric equation is a formula that quantitatively formalizes the relationship; for instance, the relationship between above-ground biomass and tree parameters such as diameter at breast height (dbh) and wood density (Basuki *et al*., 2009). It can also be used to predict a variables from other dimensions such as tree biomass based on height or diameter (Breu *et al*., 2012). Due to site conditions, allometric equations vary among species and within species.

Many researchers have established the equations to predict biomasses for various species and forests across the region. Allometric equations are categorized as follows: forest-based, urban-based, and general equations. For an urban tree, few urban allometric equations exist even though, in urban sites, trees have been reported to grow differently from a closed forest. The application of allometric equations is the most common and least destructive method for estimating carbon sequestration and storage by trees (Aguaron & McPherson, 2012). For the tropical trees, Mohd Zaki, Latif, & Suratman (2018) estimated the above-ground biomass using an equation developed by Chave *et al*., (2014); while Misni, Jamaluddin, & Kamaruddin, (2015) adopted the Kato equation.

The integration of field survey and allometric equations is a widely adopted method. For instance, Liu & Li (2012), Roxburgh *et al.* (2006), Aguaron & McPherson (2012) and Timilsina *et al.* (2014) have all used the integration of field surveys and allometric equations. Furthermore, carbon sequestration can be estimated based on empirical data from the literature. Chen (2015) estimated carbon storage and sequestration for 35 major cities in China by adopting data that was based on field surveys and biomass equations derived from a literature review.

The adoption of remote sensing and Geographical Information System (GIS) applications when with an allometric equation is an emerging approach used by researchers. Even though the application is less accurate when compared to conventional field work, it involves lower costs, higher resolutions, saves time, and employs fewer resources in collecting data. The use of remote sensing and GIS is more applicable for carbon sequestration estimation in an area that is larger and difficult to access (Vashum *et al*., 2012). Among the methods used by researchers are remote sensing (Sanga-Ngoie, Iizuka, & Kobayashi, 2012), GIS, RS-GIS (Balasundram & Husni, 2011), Quantum GIS (Gratani, Varone, & Bonito, 2016), and ArcGIS (Willcock *et al*., 2014).

Apart from these, a carbon calculator tool is a method adopted to estimate carbon sequestration. Aguaron & McPherson (2012) estimated carbon sequestration by using CUFR Tree Carbon Calculator (CTCC), which was developed by the USDA Forest Service for estimating carbon storage at Sacramento's Urban Forests. CTCC is a publicly available accounting tool for estimating carbon-related data for a single tree. This calculator provides quantitative data on the amount of carbon sequestration and storage in a tree using the biomass equation of open-growth urban trees. The information required from the tree inventory includes the species' name, size, age, and climatic zone to estimate above-ground carbon stored, total carbon stored, and carbon sequestered (Aguaron & McPherson, 2012).

3.2 Green roof carbon sequestration estimation

Table 1 demonstrates available research, which estimates the amount of carbon sequestration for green roofs. Methods for estimating carbon sequestration on green roofs is limited. Most of this research was conducted on extensive green roofs made up of grass or sedum species. None of the studies conducted used an intensive type of green roof. Most methods adopted in estimating carbon sequestration applied an experimental plot. The experiments were conducted on a new plot or existing green roofs. Research conducted by Getter (2009), Whittinghill *et al.* (2014) and Kuronuma & Watanabe (2016) adopted the same procedure involving harvesting plants, cleaning, drying, and measuring their weight in estimating the biomass; and, thus, its carbon content.

Meanwhile, Ismail (2009) used an LI-6400 Portable Photosynthesis System to measure carbon uptake or net photosynthesis of plant samples through an experimental plot on an existing roof. This method adopted is only applicable to a single plant species. Conversely, Kim, Hong, & Koo (2012) used stimulation to develop a green roof model that can give an optimum contribution to the economy and environment. The amount of carbon sequestered from different plant species was gathered from existing data. By using different plant species scenarios, the contribution of green roofs in carbon sequestration was elucidated.

Table 1: Methods for estimating carbon sequestration at green roofs

Author	Type of green roof	Method Adopted	Outcome
Ismail, (2009)	Extensive-morning glory	Experimental plot -Carbon uptake	Amount of carbon uptake (kg) per square meter
Getter (2009)	Extensive-sedum species	-12 experimental plots -Carbon analysis	Amount of carbon sequestration (g) per square meter
Whittinghill *et al.* (2014)	Semi extensive-ornamental landscape system	-13 Experiment plots (9 ground landscape and 4 green roofs) -Carbon analysis	Amount of carbon sequestration (kg) per square meter
Kuronuma & Watanabe, (2016)	Extensive-turf, grass and sedum plants	-Experimental plot Carbon analysis using growth analysis equation	Amount of carbon sequestration (kg) per square meter
Kim, Hong, & Koo, (2012)	All green roof systems	-Model analysis and simulation	Potential contribution from different scenarios

3.3 Adoption the calculator as an estimating tool

In assessing the performance of green roofs, the adoption of easily accessible tools to measure them is essential, i.e. a calculator. The calculator was adopted as a tool for measuring performance in a few studies as shown in Table 2. Grant (2007) adopted the cool roof calculator developed by the U.S. Department of Energy (DOE) to estimate energy saving by assessing green roof performance on energy. Boixo *et al.* (2012), similarly adopted the DOE Cool Roof Calculator (DCRC) to estimate the energy consumption by various types of roofs and climate design.

Meanwhile, Aguaron & McPherson, (2012), Mcpherson, Xiao, & Aguaron (2013), Russo *et al*. (2014), and Guarna (2012) adopted the

CUFR Tree Carbon Calculator (CTCC) to estimate carbon storage and sequestration of urban forests. Apart from this, six online personal carbon footprint calculators were adopted to estimate carbon footprint per person and further develop a tailor-made carbon footprint calculator (Fitzpatrick, McCarthy, & Byrne, 2015). Additionally, another publicly available calculator known as the Carbon Calculator, developed by the Environment Agency, was adopted to estimate embodied carbon in Wong *et al.* (2015).

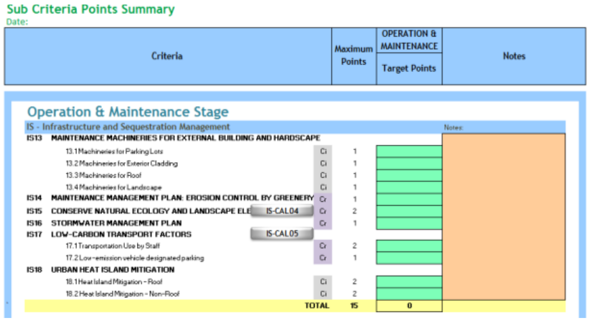
Table 2: Carbon calculator as a tool for measuring performance

Author	Method Adopted	Description	Outcome
Grant (2007)	Cool roof calculator by U.S. Department of Energy	A user-friendly web-based calculator has been developed to help designers to assess the economic impact of roofing color and make informed decisions.	Evaluate green roof performance on energy
Boixo *et al.* (2012)	DOE Cool Roof Calculator (DCRC)	The estimation of energy used corresponding to the different roof types and climatological variables. The calculator is available online.	Calculate the savings (energy and cost) per square meter of a cool roof
Aguaron & McPherson, (2012), Mcpherson, Xiao, & Aguaron (2013), Russo *et al*. (2014), and Guarna (2012)	CUFR Tree Carbon Calculator (CTCC)	CUFR tree carbon calculator (CTCC) is a Microsoft Excel spreadsheet that is freely available and offers information related to carbon for a single tree in one of 16 U.S. climate zones.	Estimate carbon dioxide storage
Fitzpatrick, McCarthy, & Byrne (2015)	On-line personal carbon footprint calculators	Examination of six online carbon footprint calculator that based on the content, emission factors used, and applicability to an individual Irish.	Estimate carbon footprint per person and develop a tailor-made carbon footprint calculator
Wong *et al.* (2015)	Carbon Calculator	The carbon calculator that was developed by the Environment Agency has been adopted mainly because it's a publicly available tool, which allow for transparent processes to assess energy efficiency and environmental impacts.	Estimate the embodied carbon

3.3 MyCREST Carbon sequestration calculator

The MyCREST carbon sequestration calculator is an accounting tool developed for the Malaysian Carbon Reduction and Environmental Sustainability Tool (MyCREST). MyCREST is a green and sustainable building rating system that aims to guide, assist, and quantify with an eye on reducing the built environments impact caused by reduced carbon emissions and environmental impact; while *t* considering a more inclusive life-cycle (Jahnkassim *et al*., 2015). It was developed from a basic calculation of individual tree carbon sequestration and was adopted by other researchers (Othman *et al.*, 2015; Othman, Zubaidah, & Kasim, 2016). By conducting a tree inventory, the data such as its dbh, height, number, and area can facilitate the estimation of carbon sequestration. The calculator provides an estimation for trees, shrubs, turf, and water sequestration (KKR, CIDB, & JKR, 2015)

The IS-CAL04 calculator is under the sub-criteria of Infrastructure and Sequestration Management, which conserves natural ecology and landscape elements (IS15) during the operation and maintenance stage (Figure 1). The IS-CAL04 calculator is a Microsoft Excel spreadsheet that is integrated with the MyCREST Scorecard and is considered a carbon-based rating tool. The calculator consists of four pages of spreadsheets, namely introduction, inventory, IS15, and formula. Data are collected through tree inventories that require data collection for all trees at the site.



Source: (KKR *et al*., 2015)

Figure 1: MyCREST carbon calculator IS15

Figures 2, 3, and 4 indicate the data/input required for calculating carbon sequestration by using the calculator IS15:

a) Landscape area: Total green roof area
b) Carbon sequestration:
   i) For grass, turf, and groundcovers: Total grass area
   ii) Water bodies: Total area of water bodies
   iii) Trees with a diameter less than 28 cm: Diameter (cm), Height (m), Number of Trees
   iv) Trees with a diameter greater than or equal to 28 cm: Diameter (cm), Height (m), Number of Trees

IS15: Conserve Natural Ecology of Landscape Plants

Building and Site Area		
Total site area within the project boundary (m^2)		m^2
Footprint of the project building (m^2)		m^2

Landscape Area		
Total green roof area (m^2)		m^2
Total green wall area (m^2)		m^2
Total grass paved carpark (m^2)		m^2
Total other landscape area (m^2)		m^2
Total landscape area, within project boundary (m^2)	0.0	m^2
Landscape area expressed as a percent of total site area excluding building footprint:		%

Source: (KKR *et al*., 2015)

Figure 2: Input for total green roof area

Carbon Sequestration

For Grass, Turf and Groundcovers		
Total Grass Area		m^2
Total Dry Weight (TDW)	0.00	kg
Total Carbon Weight (TCW)	0.00	kg
Carbon Sequestration, tCO2e	0.0000	tCO2e

For Water Bodies		
Total Water Bodies Area		m^2
*Carbon Sequestration, tCO2e	0.0000	tCO2e

Source: (KKR *et al*., 2015)

Figure 3: Input for grass, turf and ground covers

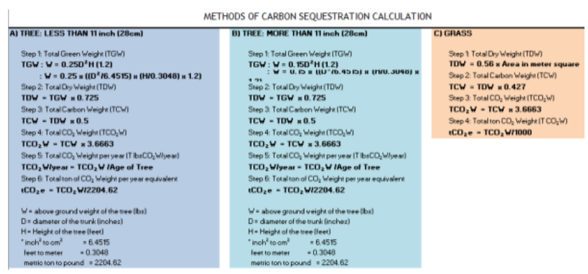
Trees with diameter LESS than 28 cm				
Diameter[1] (cm)	Height (m)	Age (years)	Number of Trees	
		0		
		0		
		0		
		0		
Total Dry Weight (TDW)			0.00	kg
Total Carbon Weight (TCW)			0.00	kg
Carbon Sequestration, tCO2e			0.0000	tCO2e

Trees with diameter GREATER OR EQUAL 28 cm				
Diameter[1] (cm)	Height (m)	Age (years)	Number of Trees	
		0		
		0		
		0		
		0		
Total Dry Weight (TDW)			0.00	kg
Total Carbon Weight (TCW)			0.00	kg
Carbon Sequestration, tCO2e			0.0000	tCO2e

Source: (KKR *et al*., 2015)

Figure 4: Input for trees based on tree inventories

Given the limited number of inputs provided by the calculator, manual calculation using Excel spreadsheets is performed by adopting the formula provided in the last section. Figure 5 depicts these calculations.



Source: (KKR *et al*., 2015)

Figure 5: Carbon sequestration formula

4.0 ANALYSIS AND DISCUSSION

This literature review of the methods for estimating tree carbon sequestration has discovered various methods adopted by researchers across the region. There are a few established methods for estimating tree carbon sequestration. As the function of intensive green roofs is mainly as residential recreational areas, it offers a diversity of plant species consisting of trees, palms, shrubs, fern, creepers, grass, and others. The plants have different parameters such as height, diameter, and crown area. The green roof provides various types of growing mediums or soils and planting depths on top of the roof structure. Plant roots will be influenced by planting depths and soils provided. Estimating carbon sequestration accurately for various types of plants on intensive green roofs is a tedious task that requires time, costs, and resources. Even though past research has used the experimental plot for green roofs, most of the research was conducted for extensive green roofs with a single or two sedum species, which is vastly different from intensive green roofs.

The adoption of the allometric equation method seems not to apply even though it has been established across the world for a long time. Most allometric equations are derived from forest trees species and information on biomass allometric equations for urban trees is lacking (Aguaron & McPherson, 2012) as even though the trees are from the same species, they vary according to the climate, site, soils, and other variables (Timilsina *et al.*, 2017).

In Malaysia, the current research on urban tree carbon sequestration has adopted Chave *et al*., (2014) the allometric equation, which fits tropical urban forests. However, owing to the conditions of intensive green roofs, the allometric equation method is not suitable. The method is not suitable for model analysis and simulation since it does not reflect the real-world situation and the current amounts of carbon sequestration on green roofs. Apart from this, a simulation study is usually performed when dealing with the many constraints in performing experiments on their real sizes on buildings (Ismail, 2009).

As for remote sensing and GIS applications, even though they provide many advantages, they only measure parameters such as height, crown size, forest density, forest type, forest volume, leaf area index, and other variables (Vashum *et al*., 2012). Remote sensing and GIS are suitable for a site that is difficult to access, and they are a cost-effective way of acquiring data for a large area. Hence, in estimating carbon sequestration on green roofs, data collection through tree inventory is the best applicable method, because it involves a small area and all trees can be measured.

A simple and user-friendly tool should be adopted for estimating carbon sequestration while considering the unique conditions of intensive green roofs that are comprised of various plant species with a limited planting depth. Adopting the carbon sequestration calculator is an option available for estimating carbon sequestration on intensive green roofs. In assessing a green roofs' performance, a method that is easily assessed and user-friendly is needed. The MYCREST carbon sequestration calculator is the only calculator available in our country, and it provides a basic carbon sequestration estimation for one tree and can be applied to all plant species. The required data for calculation such as dbh, height, and area are accessible for designers and facility managers to measure performance. Therefore, the adoption of a carbon sequestration calculator is crucial for measuring a green roofs performance based on an estimated amount of carbon sequestration.

5.0 CONCLUSION

From the literature review, it can be concluded that there are various methods for estimating carbon sequestration. The method used depend on the type of data required, costs, resources, and time allocated. The method adopted is crucial due to the unique condition of intensive green roofs. Estimation by using a carbon sequestration calculator will assist in assessing a green roofs performance towards carbon sequestration. Thus, the optimized performance of intensive green roofs can counteract CO_2 emissions and can help make intensive green roofs part of our sustainable building facilities.

REFERENCES

Aguaron, E., & McPherson, E. G. (2012). Comparison of Methods for Estimating Carbon Dioxide Storage by Sacramento's Urban Forest. In R. Lal & B. Augustin (Eds.), *Carbon Sequestration in Urban Ecosystems* (pp. 373–383). https://doi.org/10.1007/978-94-007-2366-5.

Ahmad, S., Hashim, N. M., & Jani, Y. M. (2011). Green Roofs as Best Management Practice for Heat Reduction and Stormwater Flow Mitigation. *World Applied Sciences Journal*, *13*, 58–62. https://doi.org/ISSN 1818-4952.

Ahmed, M. H., & Rumana Rashid. (2009). Thermal Performance of Rooftop Greenery system in Tropical Climate of Malaysia. *Journal of Architecture and Built Environmental*, *37*(1), 41–50.

Balasundram, S. K., & Husni, M. H. a. (2011). Geo-Spatial Technologies for Carbon Sequestration Monitoring and Management Forest Plantation Program , Department of Agriculture Technology , Department of Land Management , *7*(5), 456–462.

Basuki, T. M., van Laake, P. E., Skidmore, A. K., & Hussin, Y. A. (2009). Allometric equations for estimating the above-ground biomass in tropical lowland Dipterocarp forests. *Forest Ecology and Management*, *257*(8), 1684–1694. https://doi.org/10.1016/j.foreco.2009.01.027

Boixo, S., Diaz-Vicente, M., Colmenar, A., & Castro, M. A. (2012). Potential energy savings from cool roofs in Spain and Andalusia. *Energy*, *38*(1), 425–438. https://doi.org/10.1016/j.energy.2011.11.009

Breu, F., Guggenbichler, S., & Wollmann, J. (2012). *Manual for building tree volume and biomass allometric equations: from field measurement to prediction. Vasa*. https://doi.org/10.1073/pnas.0703993104

Chave, J., Réjou-Méchain, M., Búrquez, A., Chidumayo, E., Colgan, M. S., Delitti, W. B. C., … Vieilledent, G. (2014). Improved allometric models to estimate the aboveground biomass of tropical trees. *Global Change Biology*, *20*(10), 3177–3190. https://doi.org/10.1111/gcb.12629

Chen, W. Y. (2015). The role of urban green infrastructure in offsetting carbon emissions in 35 major Chinese cities: A nationwide estimate. *Cities*, *44*, 112–120. https://doi.org/10.1016/j.cities.2015.01.005

Ebuy, J., Lokombe, J., Ponette, Q., Sonwa, D., & Picard, N. (2011). Allometric Equation for Predicting Aboveground Biomass of Three Tree Species. *Journal of Tropical Forest Science*, *Vol. 23*(No. 2 (April 2011)), 125–132. Retrieved from http://www.jstor.org/stable/23616912

Fitzpatrick, J. J., McCarthy, S., & Byrne, E. P. (2015). Sustainability insights and reflections from a personal carbon footprint study: The need for quantitative and qualitative change. *Sustainable Production and Consumption*, *1*(January), 34–46. https://doi.org/10.1016/j.spc.2015.05.004

Getter, K. L. (2009). *Extensive Green Roofs: Carbon Sequestration Potential and Species Evaluations*. *Statewide Agricultural Land Use Baseline 2015*. Michigan State University. https://doi.org/10.1017/CBO9781107415324.004

Grant, E. J. (2007). *A Decision-Making Framework for Vegetated Roofing System Selection*. State University.

Gratani, L., Varone, L., & Bonito, A. (2016). Carbon sequestration of four urban parks in Rome. *Urban Forestry & Urban Greening*, *19*, 184–193. https://doi.org/10.1016/j.ufug.2016.07.007

Guarna, B. (2012). *An Analysis of Carbon Sequestration on Clarkson University ' s Campus*. *Sustainablity Initiatives Report, Clarkson University*. Retrieved from http://internal.clarkson.edu/green/data_reports.html

Ismail, A. (2009). *Cooling Potential of Passive Roof Treatments on the Concrete Flat Roof in Penang, Malaysia*. Universiti Sains Malaysia, Pulau Pinang.

Ismail, A., Abdul Samad, M. H., Rahman, A. M. A., & Yeok, F. S. (2012). Cooling Potentials and CO2 Uptake of Ipomoea Pes-caprae

Installed on the Flat Roof of a Single Storey Residential Building in Malaysia. *Procedia - Social and Behavioral Sciences*, *35*(December 2011), 361–368. https://doi.org/10.1016/j.sbspro.2012.02.099

Jahnkassim, S., Hashim, K. S. H. Y., Hussein, Z., & Riduan, B. (2015). *An Integrated Carbon and Sustainability Index from Green Buildings in the Tropics*.

Kamarulzaman, N., Hashim, S. Z., Hashim, H., & Saleh, A. A. (2014). Green Roof Concepts as a Passive Cooling Approach in Tropical Climate- An Overview. *E3S Web of Conferences*, *3*, 7. https://doi.org/http://dx.doi.org/10.1051/e3sconf/20140301028

Kim, J., Hong, T., & Koo, C.-W. (2012). Economic and environmental evaluation model for selecting the optimum design of green roof systems in elementary schools. *Environmental Science & Technology*, *46*, 8475–8483. https://doi.org/10.1021/es2043855

KKR, CIDB, & JKR. (2015). *MyCREST*.

Kuronuma, T., & Watanabe, H. (2016). Physiological and Morphological Traits and Competence for Carbon Sequestration of Several Green Roof Plants under a Controlled Environmental System. *Journal of the American Society for Horticultural Science*, *141*(6), 583–590. https://doi.org/10.21273/JASHS03909-16

Liu, C., & Li, X. (2012). Carbon storage and sequestration by urban forests in Shenyang, China. *Urban Forestry and Urban Greening*, *11*(2), 121–128. https://doi.org/10.1016/j.ufug.2011.03.002

Mcpherson, E. G., Xiao, Q., & Aguaron, E. (2013). A new approach to quantify and map carbon stored , sequestered and emissions avoided by urban forests. *Landscape and Urban Planning*, *120*, 70–84.

Misni, A., Jamaluddin, S., & Kamaruddin, S. M. (2015). Carbon sequestration through urban green reserve and open space. *Planning Malaysia*, *13*, 101–122.

Mitra, A., Sengupta, K., & Banerjee, K. (2011). Standing biomass and carbon storage of above-ground structures in dominant mangrove trees in the Sundarbans. *Forest Ecology and Management*, *261*(7), 1325–1335. https://doi.org/10.1016/j.foreco.2011.01.012

Mohd Zaki, N. A., Latif, Z. A., & Suratman, M. N. (2018). Modelling above-ground live trees biomass and carbon stock estimation of tropical lowland Dipterocarp forest: integration of field-based and remotely sensed estimates. *International Journal of Remote Sensing*, *39*(8), 2312–2340. https://doi.org/10.1080/01431161.2017.1421793

Nagase, A., & Dunnett, N. (2010). Landscape and Urban Planning Drought tolerance in different vegetation types for extensive green roofs : Effects of watering and diversity. *Landscape and Urban Planning*, *97*, 318–327. https://doi.org/10.1016/j.landurbplan.2010.07.005

Othman, R., Abu Kasim, S. Z., Hashim, K. S. H. Y., & Mohd Noor, N. F. (2015). Novel landscape design model system approach: Monitoring, predicting and calculating carbon sequestration rate for tourism accommodation premises green spaces. *Jurnal Teknologi*, *77*(30), 89–99. https://doi.org/10.11113/jt.v77.6872

Othman, R., Zubaidah, S., & Kasim, A. (2016). Assessment of Plant Materials Carbon Sequestration Rate for Horizontal and Vertical Landscape Design. *International Journal of Environmental Science and Development*, *7*(6), 410–414. https://doi.org/10.7763/IJESD.2016.V7.810

Roxburgh, S. H., Wood, S. W., Mackey, B. G., Woldendorp, G., & Gibbons, P. (2006). Assessing the carbon sequestration potential of managed forests: A case study from temperate Australia. *Journal of Applied Ecology*, *43*(6), 1149–1159. https://doi.org/10.1111/j.1365-2664.2006.01221.x

Russo, A., Escobedo, F. J., Timilsina, N., Schmitt, A. O., Varela, S., Zerbe, S., … Schmitt, A. O. (2014). Assessing urban tree carbon storage and sequestration in Bolzano, Italy. *International Journal of Biodiversity Science, Ecosystem Services & Management*, *10*, 54–70. https://doi.org/10.1080/21513732.2013.873822

Sanga-Ngoie, K., Iizuka, K., & Kobayashi, S. (2012). Estimating CO2 sequestration by forests in oita prefecture, Japan, by combining LANDSAT ETM+ and ALOS satellite remote sensing data. *Remote Sensing*, *4*(11), 3544–3570. https://doi.org/10.3390/rs4113544

Sultana, N., Akib, S., Aqeel Ashraf, M., & Roseli Zainal Abidin, M. (2015). Quality assessment of harvested rainwater from green roofs under tropical climate. *Desalination and Water Treatment*, *3994*(January), 1–8. https://doi.org/10.1080/19443994.2015.1015307

Timilsina, N., Beck, J. L., Eames, M. S., Hauer, R., & Werner, L. (2017). A comparison of local and general models of leaf area and biomass of urban trees in USA. *Urban Forestry and Urban Greening*, *24*(April 2016), 157–163. https://doi.org/10.1016/j.ufug.2017.04.003

Timilsina, N., Escobedo, F. J., Staudhammer, C. L., & Brandeis, T. (2014). Analyzing the causal factors of carbon stores in a subtropical urban forest. *Ecological Complexity*, *20*, 23–32.

Townshend, D., & Duggie, A. (2007). *Architectural Services Department Study on Green Roof Application in Hong Kong Final Report URBIS LIMITED*. *Design*.

Vashum, K. T., Jayakumar, S., & T. Vashum, K. (2012). Methods to Estimate Above-Ground Biomass and Carbon Stock in Natural Forests - A Review. *Journal of Ecosystem & Ecography*, *02*(04), 1000116. https://doi.org/10.4172/2157-7625.1000116

Whittinghill, L. J., Rowe, D. B., Schutzki, R., & Cregg, B. M. (2014). Quantifying carbon sequestration of various green roof and ornamental landscape systems. *Landscape and Urban Planning*, *123*, 41–48. https://doi.org/10.1016/j.landurbplan.2013.11.015

Willcock, S., Phillips, O. L., Platts, P. J., Balmford, A., Burgess, N. D., Lovett, J. C., Lewis, S. L. (2014). Quantifying and understanding carbon storage and sequestration within the Eastern Arc Mountains of Tanzania, a tropical biodiversity hotspot. *Carbon Balance and Management*, *9*, 1-17.

Wong, P. S. P., Lindsay, A., Crameri, L., & Holdsworth, S. (2015). Can energy efficiency rating and carbon accounting foster greener building design decision? An empirical study. *Building and Environment*, *87*, 255-264.