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Tree Canopy Cover and Its Potential to Reduce CO_2 in South of Peninsular Malaysia

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Urban trees provide a wide range of ecosystem services that can address climate-change mitigation and adaptation. In this study, the tree cover and their potential to store carbon in two cities (Johor Bahru and Pasir Gudang) that are developing rapidly in the south of Peninsular Malaysia have been estimated. Tree coverage was mapped using Landsat 8 Thematic Mapper satellite data for year 2016. Various digital image processing techniques namely Maximum Likelihood and a sub-pixel classification were applied to obtain tree coverage of urban trees/forest, mangrove and oil palm. Results of the study show that natural tree coverage (forest and mangrove) in the cities range between 19 % and 47 % and generally Pasir Gudang has more tree coverage compared to Johor Bahru. Johor Bahru is the centre for various business and cultural activities, thus more built up areas are found in the city. On average, trees in the cities store approximately 796,136 t carbon or 2,919,164 t CO_2-eq which is about 18 % of the total CO_2–equivalent emissions projected for 2025 under the Business as Usual (BaU) scenario. The mapping of tree canopy cover and estimating their potential to store carbon is important for assessing climate change mitigation.

1. Introduction

CO_2 is the main greenhouse gas that is responsible for global warming and climate change. Although cities cover only a small fraction of land, they are responsible for 75 % of global CO_2 emission (Olivier et al., 2016). This situation will become worse when more than 70 % of Asian population will be residing in cities by 2050 and in Malaysia, three quarter of its population is expected to live in cities by 2020 (United Nations, 2015). Increased industrial, housing, and transportation activities in cities will exacerbate the existing environmental problems such as air pollution (Kanniah et al., 2014), elevated surface and air temperature (Sheikhi et al., 2015), flood, and landslides (Elmahdy and Mostafa, 2013). Many countries including Malaysia are taking various efforts to reduce the carbon footprint of cities and mitigate the environmental problems related to climate change.

Although urban areas are the primary sources of CO_2, urban forests (trees in woodlands, wetlands and other natural areas, parks, parking lots and street trees) can have the capability of transforming CO_2 and water into biomass through photosynthesis and store carbon in stems, roots and branches (Nowak and Crane, 2002). Urban forests are also influencing the energy cycle by providing shade and releasing water vapour through evapo-transpiration, influencing the carbon, water, and energy cycles and affect the local climate and its change (Díaz-Porras et al., 2014). Urban forests are promoted as nature-based solution for climate change in cities, but their role in local and global carbon cycle is not well studied. The potential of urban forests in sequestrating and storing carbon has been demonstrated in several studies, mostly in northern America (Nowak et al., 2013) and Europe (Davies et al., 2011). In the Asian region there has been an increased interest in carbon sequestration and storage by urban trees due to their potential in reducing the atmospheric and surface temperature via shading and CO_2 absorption (e.g. Yang et al., 2005). It is important for cities in

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Asia to understand the role of trees in storing CO_2 as a nature-based solution to curb the increasing CO_2 in the atmosphere.

Carbon sequestration and storage services provided by urban trees can be assessed based on tree canopy cover (fraction of urban area covered by trees) (Strohbach and Haase, 2012) and land use/land cover change (Pasher et al., 2014). Estimating tree canopy cover is also important to assess air pollutant removal in cities. Urban forest canopy cover can be estimated using remote sensing data that provide continuous temporal data covering large areas. The objective of this study is to map urban forest canopy cover in two cities that are fast developing in the south of Peninsular Malaysia using remote sensing images and to estimate the carbon storage potential of the urban forests. The mapping and estimation of the carbon storage potential of urban forests is critical for urban planning and for understanding the role of green cover in carbon balance and climate change of urban landscape.

2. Study area

Two cities, namely Johor Bahru (JB) and Pasir Gudang (PG) located in Iskandar Malaysia (IM) region in the state of Johor were selected in this study (Figure 1). IM is a special economic region that is growing fast to bring economic and infrastructure investments. Five local government authorities are involved with the development process. JB is the capital city of Johor and one of the focal points administered by JB City Council, covering an area of 32,721 hectares. Among the key economic activities of this flagship zone are financial services, commerce and retail, electrical and electronics manufacturing, food processing etc. Meanwhile, PG is administrated by PG Municipal Council (MPPG) and covers an area of 36,887 hectares. PG is located within the eastern gate development flagship zone and it is a main industrial port city in the south east coast of Johor state. Two ports namely Johor and Tanjung Langsat handle more than 300 manufacturing companies, largest edible oil tankage facility and bulk cargo such as liquefied petroleum gas and dangerous chemicals. The main land cover/ land use in these cities include urban/settlements, agricultural land use (oil palm), forest, mangrove, open space and recreational areas.

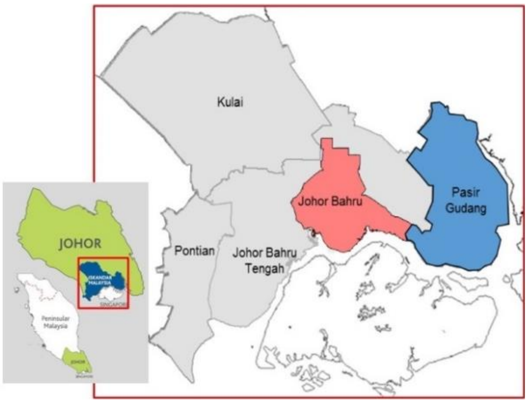

Figure 1: Location of Johor Bahru and Pasir Gudang within Iskandar Malaysia region in south of Peninsular Malaysia

3. Data and Methodology

The main data used in this study is a Landsat 8 satellite image. The data was captured using Operational Land Imager and Thermal Infrared sensors. Data captured on 30 April 2016 was downloaded from the United States Geological Survey (USGS) website (USGS, 2016). Landsat satellite image with 30 m spatial resolution used in this study is geo-referenced by the data provider and it is available for free. The image used in this study was covered by approximately 10 % of clouds. The image was first pre-processed for mask out clouds and associated shadows, corrected for atmospheric distortion and to calibrate its digital numbers to reflectance. These pre-processing were performed using the Carnegie Landsat Analysis System (CLASlite) algorithm version 3.3 (Asner et al., 2009). The same program (CLASlite) was also used to classify green cover in Kuala Lumpur. Although CLASlite was originally developed to detect forest cover, in this study it was modified to identify urban tree covers as it was proposed by Kanniah (2017). CLASlite uses the Automated Monte Carlo Unmixing (AutoMCU) model to classify each pixel into its fractional cover of photosynthetic vegetation, non-photosynthetic vegetation and bare substrate (Asner et al., 2009).

Since JB and PG are covered by various types of trees mainly forest/urban trees, oil palm, and mangrove, a pixel-based classification technique was also used to obtain different land/tree covers in the two cities. A most commonly used maximum likelihood classification technique was used and a total of five different tree cover/land cover classes were obtained. Training samples (homogeneous pixels representing each land cover i.e. forest/urban trees, oil palm, mangrove, urban, and vacant lands) were selected from the satellite image to run the classification. A total of 50 training samples (polygons) covering 40 – 50 pixels in each polygon were used to classify the image. Land use map of Johor dated 2010 (scale 1 : 250,000) was also referred to ensure correct training samples were chosen. The classified images were validated for their accuracy using another independent set of data taken from Google Earth maps (a technique used by Cracknell et al. (2013)) A total of 20 polygons for urban land cover and 10 polygons for the rest of the land covers (each polygon containing 50 pixels) were used to validate the classification results using confusion matrix that provides user, producer and overall accuracies and kappa coefficients (Congalton, 1991).

4. Results and Discussion

4.1 Tree cover mapping

Tree cover as detected by Claslite program is shown in Figure 2. A total of 6,584 ha of trees (20 % of the total land area) are covering JB and 13,232 ha (36 %) of trees are covering PG. The results are produced with high overall accuracy of 87 % for JB and 65 % for PG (data not shown).

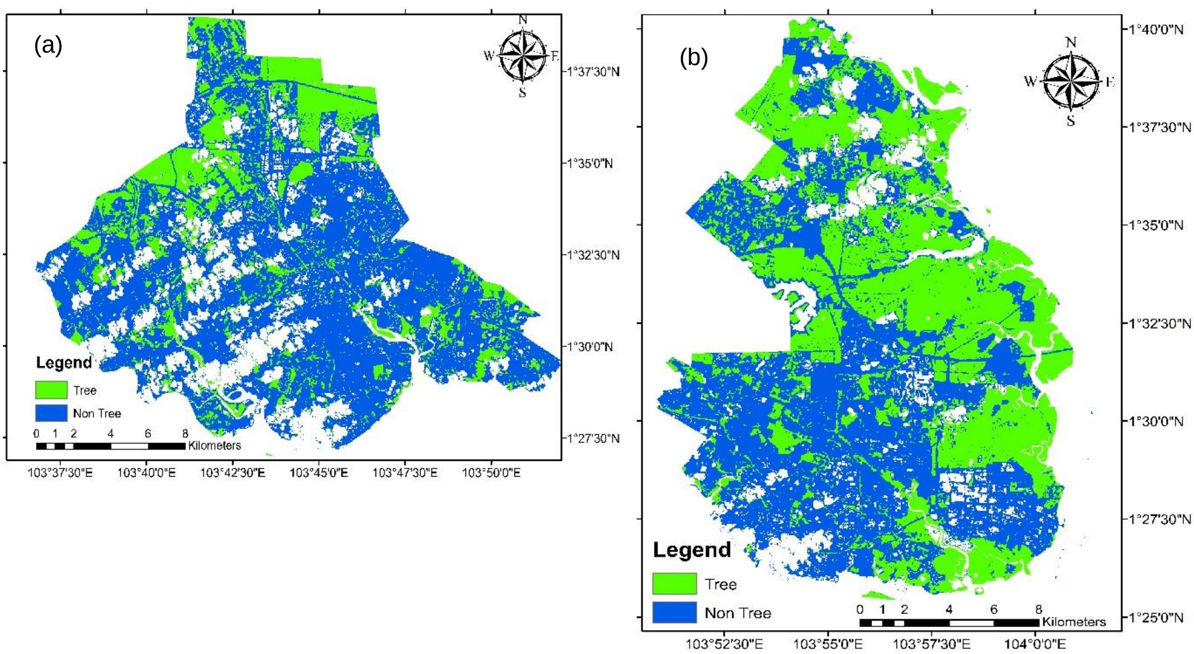

Figure 2: Tree cover in Johor Bahru (a) and Pasir Gudang (b). White colour inside the city boundaries show water bodies, clouds and cloud shadows that were masked out from the images

Claslite cannot differentiate types of trees, but in order to calculate carbon storage, information on the types of trees present in urban and their coverage is important as different coefficients of carbon storage will be used for different types of trees. The results of classification of different types of land/tree cover is shown in Figure 3. A total of five land or tree cover/ land use classes were obtained from the classification of Landsat 8 image (Figure 3) and their accuracies are shown in Table 1. The overall accuracy of the classified images is 78 % for JB and 71 % for PG, while the Kappa are 0.70 and 0.61 for JB and PG. The accuracy of each land cover/land use classes is detailed in Table 2. Generally, all three classes of vegetation (forest/urban trees, mangrove and oil palm) have lower user/producer accuracies that may be attributed to the spectral similarity of these classes within the 30 m resolution of Landsat data. This may have caused confusion to separate them effectively. Urban and vacant land classes which have distinctive spectral reflectance can be separated from vegetation with high accuracy (Table 1).

Classified satellite data shows that large portion of these cities are dominated by urban surface (52 % in JB and 13 % in PG). Vacant lands constitute approximately 8 % in JB and 13 % in PG. In PG some urban surfaces are classified as vacant land due to their proximity with urban areas. In terms of tree cover 55 % of

PG is covered by trees, while only 26 % of JB is covered by trees. From this amount natural tree coverage (mangrove and forest) is only 47 % in PG and 19 % in JB. In a previous study Kanniah et al. (2015) detected a complete loss of natural forest cover between 1989 and 2014 in PG. These 2 cities were found to have lost 626 ha and 1,159 ha of tree cover in just 2 years (2012 - 2014) (Kanniah and Ho, 2017).

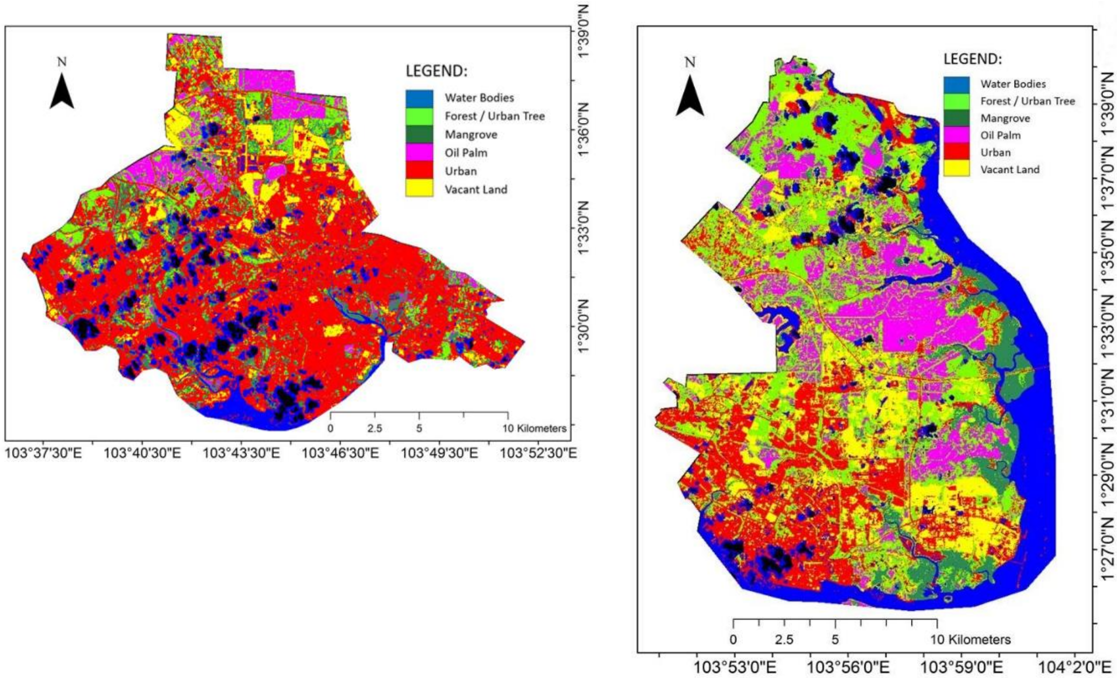

Figure 3: Classified Landsat 8 satellite data covering Johor Bahru (right) and Pasir Gudang (left). Clouds and shadows were masked out from the satellite image

Table 1: Accuracy assessment of the classified Landsat 8 images.

	Johor Bahru		Pasir Gudang	
Tree/Land cover Class	Prod. Accuracy (%)	User Accuracy (%)	Prod. Accuracy (%)	User Accuracy (%)
Forest / Urban trees	31.15	36.54	50.74	25.46
Mangrove	52.11	45.68	68.56	79.96
Oil palm	60.47	81.89	42.19	57.45
Urban	84.29	79.42	63.59	91.40
Vacant Land	79.87	80.38	80.18	42.38
Unclassified	90.80	84.84	84.16	72.60
Overall Accuracy	77.6		71.1	
(Kappa Coefficient)	(0.70)		(0.61)	

Table 2: Percentage of various land cover in Pasir Gudang and Johor Bahru

Land cover	Johor Bahru		Pasir Gudang	
	Total land cover (ha)	% land cover	Total land cover (ha)	% land cover
Forest/Urban tree	2,680.4	8.3	9,838.2	26.81
Mangrove	3,596.5	11.1	7,544.1	20.6
Oil Palm	2,013.5	6.21	2,682.8	7.3
Urban	16,934.2	52.3	4,789.5	13.1
Vacant Land	2,623.4	8.1	4,696.7	12.8
Unclassified	4,553.9	14.1	7,150.1	19.5
Total	32,401.9	100	36,701.4	100

4.2 Potential carbon dioxide (CO_2) reduction by trees

We estimated carbon storage potential of trees in the two cities based on previous studies established in Malaysia (Table 3). The results of previous studies show that mangrove has the highest capacity to store carbon compared to urban forest and oil palm. Trees grown in urban environment tend to have less aboveground biomass (AGB) than forests due to limited availability of fertile soil and other resources and human activities such as pruning. Total carbon storage was obtained by multiplying average carbon per ha (from previous studies) with total tree canopy cover.

Table 3: Carbon storage potential of urban trees in Johor Bahru and Pasir Gudang

Tree Cover	Average carbon per hectare based on Previous Studies ($t\ C\ ha^{-1}$)	Carbon Storage in this study (t C)		Carbon storage (t CO_2-eq)	
		Johor Bahru	Pasir Gudang	Johor Bahru	Pasir Gudang
Forest/Urban trees	40 (Kanniah, 2016)	107,216	393.528	393,125	1,442,936
Mangrove	50 (Hamdan et al., 2014))	179,825	377,205	659,358	1,383,085
Oil Palm	28 (Kho and Jepsen, 2015)	56,378	75,118	206,719	275,433

On average, trees found in JB and PG store approximately 796,136 t C or 2,919,164 t CO_2-eq which is about 18 % of the total CO_2–equivalent emissions projected for 2025 under the Business as Usual (BaU) scenario for the cities (Ho et al., 2015). Absorption and storage of CO_2 by trees found in urban environment is important to reduce CO_2 emission in cities and for climate change mitigation. The total carbon storage estimated in this study may be overestimated as mangroves and urban trees which have higher average carbon storage are classified as oil palm (data not shown). Using high resolution aerial photographs, Pasher et al. (2014) estimated carbon storage of urban trees in Canada to be ~34 million t C with ~2.5 million tons CO_2 sequestration annually. In USA, Nowak and Crane (2002) found an uptake of 712 million t C with 22 million t C/y. In Asia only, several studies have been conducted mainly in China, Africa, Singapore and Bangladesh. Yang et al. (2005) for example found that trees in Beijing, China, stored about 0.2 million tons of CO_2. Street trees are also found to contribute significantly to China's terrestrial vegetation carbon storage (Guo et al., 2014). In Bangladesh, Rahman et al. (2015) reported that roadside trees store significant amount of carbon where they can contribute to the United Nations Framework on Climate Change's carbon mitigation and adaptation mechanism.

The findings of the current study show that trees in JB and PG can directly assist to absorb excess CO_2 from the atmosphere. Other significant roles of large canopy trees in urban forests, recreational parks, and streets include providing shade and reducing the surface and atmosphere temperature by evaporative cooling (Jaganmohan et al., 2016), removing airborne particles (Selmi et al., 2016), and reducing the risk of floods due to storm in cities (Berland et al., 2017). In this way, not only trees can influence the carbon but also can affect the water and energy cycles in the urban environment and subsequently influence the urban micro climate and its change. It is highly recommended that all municipal councils in Malaysia should set a canopy cover target such as 30 % (Kanniah, 2017) to increase tree cover in cities.

5. Conclusion

Cities experience high levels of greenhouse gases particularly CO_2 concentration compared to rural areas. This has resulted in elevated temperature or urban heat island phenomenon in cities. Although various actions are taken by cities around the world to reduce CO_2 concentration, trees found in cities are a nature-based solution to curb excessive CO_2 levels. Urban trees also provide various other ecosystem services and functions. Increasing urban tree cover is important for increasing the livability of urban dwellers in Malaysia.

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