EXTRACTION AND ASSESSMENT OF URBAN GREEN COVER USING REMOTE SENSING DATA

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ABSTRACT: Mapping green cover in cities is vital for environmental protection and sustainable urban planning. However, only limited studies are available to monitor and quantify green cover in Malaysia. The aim of this study was to provide an overview of data and methods that can be used to map and monitor green cover in Malaysian cities. Medium resolution satellite data was found to provide acceptable mapping accuracies when sub-pixel classification techniques were used. However, if sufficient number of training data were used, per pixel techniques can produce higher classification accuracies. High spatial resolution aerial photos and satellite images are preferred over medium resolution images to extract detailed vegetation information that are crucial for management and planning purposes. The role of emerging technologies such as LiDAR is tremendous in mapping vegetation cover as height information significantly increased mapping accuracy. Fusion of LiDAR with medium and high resolution imageries is a methodological innovation for urban green cover mapping. These techniques along with other remotely sensed data are recommended to be used for urban vegetation mapping in Malaysia.

1. INTRODUCTION

Green cover can be defined as any surfaces covered with vegetation in cities, such as parks, recreational and reserved forests, residential and cemetery gardens, and street trees (Kabisch and Haase, 2013). When viewed from above using aerial photos and satellite images (Figure 1) green cover refers to the layer of leaves, branches, and stems of trees and shrubs and the leaves of grasses that cover the ground (Sexton et al., 2013). Green cover, can support to mitigate and/or adapt the impacts of climate-change by sequestering atmospheric CO_2 (Tang et al., 2016; Nowak et al., 2013), filtering the polluted air (Selmi et al., 2016), reducing surface and air temperature (Jaganmohan et al., 2016), and reducing energy use in cities (Zhang et al., 2014). Moreover, strategically planted trees can assist in managing storm water to reduce flash floods. (Kok et al., 2016). From the perspective of social well-being of urban residents, open spaces such as recreational parks support social interaction and public health (Foo, 2016). The role green cover in biodiversity conservation is also tremendous (Threlfall et al., 2017). These functions of urban green cover significantly contribute to achieving the goals (goals 3, 11 and 13) of sustainable development.

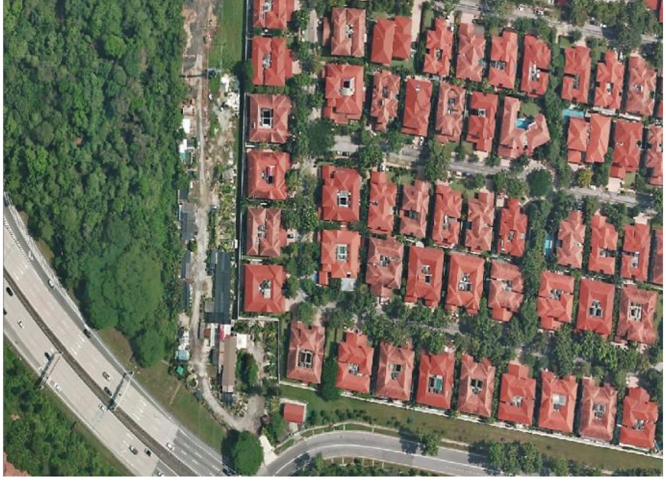

Figure 1: A subset of aerial photo showing a green space in Kuala Lumpur, Malaysia (Image courtesy of Kuala Lumpur City Hall, 2017).

However, growing population density in cities force development to encroach into green spaces particularly forests and other vegetated surfaces (Schäffler and Swilling, 2013; Brunner and Cozens, 2013; Kabisch and Haase, 2013). This issue is critical in developing countries like Malaysia because by the year 2020, because three quarter of Malaysian population is expected to be residing in the urban areas in the light of its aspiration to become a developed country by 2020 (United Nation, 2015). Some large cities in Malaysia such as Kuala Lumpur (west coast), Penang (north) and Johor Bahru (south) in Peninsular Malaysia have already lost significant amount of green areas since 1980s (Teh, 1989; Kanniah et al., 2015; Kanniah and Siong, 2017; Kanniah, 2017) as a consequent of commercial and residential developments. Nevertheless, systematic studies to map green areas and to quantify their changes over time are not extensively available in the context of Malaysian cities. Obviously there is a need to map and quantify green cover in Malaysia as currently most cities do not have a complete up to date green cover database. The objective of this study is (i) to review existing literature pertinent to urban green cover mapping in Malaysia and (ii) to provide an overview of techniques that can be used to map urban green cover in Malaysia. This overview covers methods using remotely sensed data from earth observation satellites as green cover at a city scale can be extracted and monitored continuously and coast effectively using remote sensing data.

1.1 Urban green cover studies in Malaysia

Only a very limited number of studies have mapped and monitored green cover in Malaysian cities. Teh (1989) reported that large green areas were lost in Kuala Lumpur (KL), the capital city of Malaysia as a consequent of urban development in the 1980s. He used aerial photographs with cm spatial resolution to map green space in KL and its vicinity. Landsat Thematic Mapper data were used in another study to map forest cover and other surfaces in the island of Penang in north of Peninsular Malaysia (Tan et al., 2010. A decreasing forest cover pattern was reported in the study. Spot satellite data of 2 periods (1990 and 2001) and Ikonos of 2010 was classified by Norzailawati (2013) and found that green area in Kuala Lumpur decreased 647.47 ha or 2.66% per year between 1990 and 2010. In a recent study, Kanniah and Soing (2017) analysed tree cover data obtained from Landsat images covering 12 years (2000-2012) in Kuala Lumpur, Penang, Melaka and Iskandar Malaysia region in Peninsular Malaysia. The data showed a loss of 4 - 17 percent of tree cover from their total land area in the cities. In a recent study (Kanniah, 2017) reported a decrease of 3% in the total green coverage in Kuala Lumpur from 2001 to 2010. However, it increased 4% from 2014 to 2016 and the green coverage in 2016 was 30%. It was also found that some protected public parks and recreational forest lost their green areas over time.

2. METHODS TO MAP URBAN GREEN COVER

In this section remotely sensed data with different spatial resolutions and their potential to extract urban green cover is reported. Data acquired by different platforms, their advantages and limitations to map green cover are also discussed in this section.

2.1 Medium resolution

Remotely sensed data with medium spatial resolution (30m) contribute significantly to map green cover over large cities. One of the widely used medium resolution data is provided by the Landsat program. The long term availability of these data since 1972 provides a unique opportunity to study the temporal pattern of vegetation growth and changes in cities. This data also enables synoptic mapping as a result of its larger footprint and it is available for free. These features allow the data to be used for purposes that do not require detailed mapping of individual vegetation elements. Nevertheless, these data may reduce the mapping accuracies due to the mixture of many land use/land cover types captured within their IFOV. Advance image processing techniques such as spectral unmixing may overcome the issue of mixed pixels by deconvolving each pixel into fractional cover of various features present in the pixel (Van de Vooede, 2008) tested three spectral unmixing techniques namely linear regression analysis, linear spectral unmixing (LSMA) and multi-layer perceptrons (MLP), to obtain sub-pixel images derived from end members based on the 3 approaches above.

In a recent study Kanniah (2017) obtained fractional green and tree cover images for Kuala Lumpur using Landsat images. The Automated Monte Carlo Unmixing (AutoMCU) model embedded in CLASlite (Asner et al., 2009) software was employed in this study. Each Landsat image pixels with 30 m x 30 m was de-convolved into fractional loads of photosynthetic vegetation, non-photosynthetically active vegetation and bare substrate. This technique produced both total green (trees, shrubs, grasses) and tree covers over a period of 15 years (Figure 2).

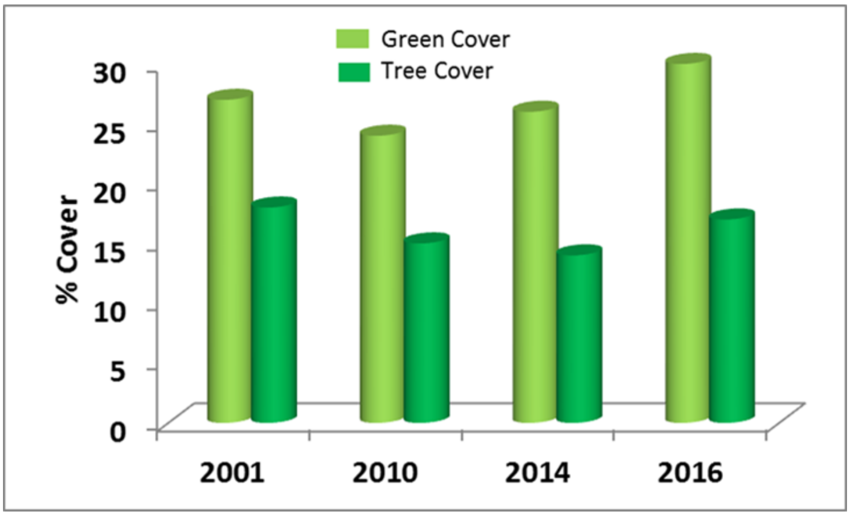

Figure 2: Total green and tree cover and their changes over time in Kuala Lumpur, Malaysia (source of data: Kanniah, 2017).

Although sub pixel techniques are reported to be superior to per pixel methods, Li et al. (2014) argued that per pixel image classification techniques can produce high land cover mapping accuracies for medium resolution satellite data covering urban areas when sufficient number of training data are used. They studied 15 per pixel classification methods for land cover classification in the city of Guangzhou, China using Landsat imagery. The different techniques used in the study produced only small differences in overall accuracies. Similarly Kopecka et al. (2017) used a medium resolution (10 m) optical data from Sentinel 2A to classify urban green space in three cities in Slovakia. A traditional maximum likelihood classification technique was applied to the images to derive tree cover and non woody cover which was then sub-divided into 15 classes based on their urban ecosystem services with an overall accuracy over 85% and kappa coefficient of 0.862. Since 10 m spatial resolution caused Commission and Omission errors between tree and non-woody vegetation it was recommended to use high spatial resolution satellite data with less than 5 m.

2.2 High resolution

Although medium spatial resolution data have been shown to be effective in deriving urban green cover, high spatial resolution data are always a preference for achieving high mapping accuracy. These data are necessary when detailed vegetation mapping is needed for research (structural tree data to model potential carbon sequestration, air pollution etc.), planning, management and policy implication. As early as 1996 Nowak interpreted aerial photos to produce percent tree cover and total green space data for 68 cities in the U.S. He proposed four main techniques o accomplish the task namely crown cover method, transects/line method, dot method and scanning method. Among these techniques, the dot method (placing dots on an image and land covers belong to the dots are recorded) is incorporated in the i-Tree software developed by the United States Department of Agriculture (USDA) to estimate the percentage of tree and other green/surface cover in cities. This method is interfaced with "Google" database that comprises of high spatial resolution aerial photos and satellite images such as Worldview, Ikonos, Quickbird, and Geoeye.

Myeong et al. (2001) used a "hybrid" or "guided clustering" method that combines supervised and unsupervised classification approaches to classify colour Infra-red aerial image (0.61m) in Syracuse, New York. A total of 6 types of band combinations were used using the original three bands, Normalized Difference Vegetation Index (NDVI), texture, post-processing with sieve and majority filter functions to enhance the classification results. The results show that when the original bands were combined with NDVI and texture information an overall accuracy of 85% could be achieved compared to only 75% with using only the 3 spectral bands. However, confusion occurred between bare soils and impervious surface (low producer and/or user accuracy of bare soil). Grass with shadow and trees with low texture were misclassified as trees and grasses respectively. The technique proposed in this study can be applied in Malaysia as aerial photos are increasingly available especially for large cities like Kuala Lumpur although future missions should also consider employing NIR cameras to obtain NDVI data. Local surface height data should be integrated to effectively separate herbaceous cover from shrub and trees. For this Digital Elevation Model (DEM) from Shuttle Radar Topography Mission (SRTM at 30 m resolution) and height information from LiDAR or photogrammetric processing can be used.

Similarly, another study by Zhang (2001) extracted urban treed area by integrating textural and spectral information, with 0.5m RGB bands and 0.25m NIR band. Texture information for B, G, and NIR were computed and conditional variance detection model was applied to eliminate the edges of other objects in order to better detect tree textures. Unsupervised (ISODATA) spectral classification and textural classification were employed. The resultant classification images were then used to extract the final treed area. When texture information was integrated with the four spectral bands the User's accuracy increased from 61-73% to 94 -97% and the Kappa statistic value jumped markedly from 0.54-0.58 to 0.92-0.97. The approach developed in this study was based on the analysis of textural and spectral characteristics within a local operation window, the effects of canopy closure, shadow, and sun angle however, were not taken into account.

Although aerial photos provide very high resolution and cloud free images, the use of remotely sensed satellite images are increasingly used to derive urban vegetation mainly because satellite images are less expensive, covers large urban space and some data with more spectral bands enable derivation of detained vegetation classes. Ikonos images and DSM generated from stereo paired Ikonos images were used to discriminate 10 classes of vegetation in Dunedin, New Zealand by Mathieu and Aryal (2005). A nearest neighbor object-oriented method was used to classify Ikonos image into different vegetation types and water. Object oriented technique uses multi-resolution segmentation technique (with the aid of spatial and spectral information of the input data. Image objects were constructed through the object oriented technique to extract patches of vegetation with different sizes. With these techniques higher mapping accuracies of more than 70% was achieved for all three strata of vegetation covers. Object orientation (rule based technique) was applied on QuickBird data (RGB and NIR) by Li et al. (2010) to discriminate forest, grassland, and thick grassland with an overall accuracy of 93.72% and Kappa value of 0.82. The higher accuracy was possible due to the integration of ancillary data such as urban vegetation inventory data layer, topographic and land use maps and a digital elevation model (DEM).

While, high spatial resolution aerial and satellite data could increase both the accuracy and details of vegetation mapping in cities, the main drawback of some of the data are:

(i) They are limited by spectral resolution. Very high resolution data such as Quickbird, Ikonos, and Geoeye have only 3 visible bands and 1 near infra-red. With these bands different types of vegetation, different tree species and the mixture of shrubs and grasses for example cannot be separated effectively.

(ii) Lack of height data hinders the separation of vegetation with similar densities but different heights (i.e. trees and shrubs).

Consequently, hyperspectral and LiDAR data are increasingly being applied to map urban green covers. Degerickx et al. (2017) used airborne hyperspectral data (2m spatial resolution and 218 spectral bands) to classify green area in Brussels, Belgium into their functional classes. Although the Multiple End member Spectral Mixture Analysis (MESMA) – a spectral unmixing technique was applied, high spectral similarity particularly between different types of scrubs and grasses was found. Clearly, height information could solve the problem.

2.3 Emerging technologies to map urban green cover

Light detection and ranging (LiDAR) is one of the latest technology used to acquire terrain and surface elevation data with an accuracy of ~ ±30 cm in the vertical and horizontal planes (Webster et al., 2004). Digital surface and elevation models derived from LiDAR data have been implemented to classify different vegetation types based on their structural height. Brennan and Webster (2006) adopted an object-oriented land cover classification scheme to classify short and tall trees of deciduous and coniferous trees in Annapolis valley, Nova Scotia with the aid of height information from LiDAR. The average accuracy of the 10 classes obtained in this study (include the classes of short and tall trees) was 94%. However, misclassification occurred between buildings and tall trees.

Fusion between optical and LiDAR is a methodological innovation in urban green cover mapping. In an earlier study although Charaniya et al. (2004) incorporated aerial photograph (luminance, and intensity) with LiDAR (normalized height, height variation, multiple returns,) they could derive only four classes from the LiDAR points (trees, grass, roads, and roof) with an accuracy of 66-85%. It should be noted that they used Gaussian-based classification method compared to object oriented rule based classification as used in Brennan and Webster (2006).

In another study Chen et al. (2009) used pixel based classification and object oriented techniques to classify 9 land use/land cover classes in the city center of Kuala Lumpur, Malaysia. NDVI was used to extract vegetation information from Quickbird image (0.6 m pan sharpened image) and DSM from LiDAR was used to differentiate between grass and shrubs. As one could expect object oriented produced higher overall accuracy compared to the pixel based techniques (69.12% versus 89.40%). Although water, shadow, high crossroad and high/low buildings were classified well with the aid of LiDAR data relatively lower producer accuracy for vacant land (65.88), and relatively lower user accuracy for roads (59.68%) were obtained. In terms of green covers, only two classes (grass and shrubs) were identified. Mapping and quantifying trees present in roadsides and in the permanent forest reserve in the city centre are important for planning purpose. However this study did not report the existence of any trees.

Singh et al. (2012) **e**valuated the potential of fused LiDAR-TM data in discriminating land covers in Charlotte, North Carolina, USA. The supervised maximum likelihood (ML) and classification tree (CT) methods were used to classify the fused dataset at resolutions ranging between 1m and 30m. Results of the study demonstrated that the fused dataset at 1 m produced highest accuracy of 85% compared to the classification results obtained using LiDAR data alone or Landsat data alone. However, the use of LiDAR data could produce higher accuracy when advance image processing techniques are employed (Brennan and Webster, 2006). Banzhaf and Kollai (2015) fused LiDAR (2 m spatial resolution) and digital orthophotos with 0.8m spatial resolution and 4 spectral bands (visible and near infra-red) to monitor urban tree cover in Leipzig, Germany. NDVI derived from the orthophotos, DEM derived from LiDAR were synergized in object-based image analysis to differentiate trees from bushes and lawn. Unfortunately, young trees are still hard to be differentiated from bushes due to their similar height.

3. LESSONS LEARNED, FUTURE DIRECTION AND SUMMARY

From the review of previous studies the following lessons are learned:

(i) Medium spatial resolution remote sensing images are still a valuable source of data to map temporal changes of green cover in large urban areas. The use of sub- pixel classification techniques such as, Claslite are recommended.

(ii) High spatial resolution satellite data can provide improved mapping accuracy. Advanced image processing techniques such as object oriented classification can reduce the time used to collect field data and errors caused by inaccurate field data.

(iii) Cloud cover is a major issue in optical images captured over tropical regions like Malaysia. Active microwave data such as Alos Palsar 2 (25m data is freely available) data can used to map urban green cover. A combination of texture information and manipulation of different polarizations may provide better results. Another freely available data from Sentinel 2A is worthwhile investigated of its potential for monitoring urban green areas in Malaysia. The frequent revisit period of this data can partly solve the issues of cloud cover in optical images.

(iv) LIDAR is one of the emerging technology providing high spatial and all weather data. It provides above-ground height information that can be used to differentiate vegetation with different height such as trees, shrubs and grasses. LiDAR alone was found not to provide acceptable accuracy in mapping vegetation classes. So, fusion of LiDAR with medium or high spatial resolution multi spectral images is guaranteed to produce better mapping accuracies.

Various remotely sensed data and image processing techniques as discussed in this paper are essential to monitor various types of green cover in cities. Such data are essential to assess environmental quality and quality of life because higher-volume green cover, like trees, have a more profound effect than low-volume vegetation like grass on removing pollution, lowering temperature, providing shade, and removing CO_2.

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