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Quantifying Green Cover Change for Sustainable Urban Planning: A case of Kuala Lumpur, Malaysia

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Abstract

Despite the numerous benefits of urban green cover, urban land development has led to its destruction and degradation, including in Malaysia. In this study, time series Landsat satellite imagery were used to monitor green cover changes in Kuala Lumpur (KL), the largest and capital city of Malaysia. An advanced satellite image processing technique that considers the mixed-pixel problem was employed to determine the fraction of green cover in each Landsat pixel. Results show that the total green coverage in Kuala Lumpur decreased by 3% over the first study period, from 6,564 ha in 2001 to 5,891 ha in 2013. However, it increased by 4% in the second, from 6,215 ha in 2014 to 7,310 ha in 2016, and now green cover is 30% of the total land area of KL. These periods were selected to observe the changes in green cover before and after implementation of the "Greening KL" program, which was aimed to plant 100,000 trees in KL by year 2020. Most of the increase in green cover was contributed by trees planted along streets and in recreational parks. Other findings include a loss of ~9% of green cover in two public parks compared to their total gazetted area, and a loss of green area in other forested parts of KL. Focus group discussions and structured interviews with public, private and non-governmental organisations indicate that green-cover losses can be partly attributed to weak regulations and their poor enforcement. Opportunities to protect and increase green cover in KL are also explored in this study. Such approaches are urgently needed before most of the green areas disappear from the landscape of KL, exacerbating the existing environmental problems in the city.

Keywords: Urban forest, Tree cover, Remote Sensing, Claslite, Public-private partnership, Gazette

1. Introduction

Consistent with global trends, 75% of the Malaysian population is expected to live in urban areas by 2020 (United Nation, 2015a), the same year by which Malaysia's government aspires to transition to developed country status. Rapid urban population growth and the growing demand for development have placed tremendous pressure on vacant, open and green spaces in Malaysian cities (Gairola and Noresah, 2010). Despite their numerous benefits, urban green spaces have been utilized to develop housing, industry, transport and other urban infrastructure (Teh, 1989; Tan et al., 2010; Kanniah et al., 2015). Such changes may exacerbate the existing environmental problems related to climate change such as air pollution (Kanniah et al., 2016, Zaman et al., 2017), temperature increases (Morris et al., 2015), flood and landslides (Elmahdy and Mostafa, 2013).

"Green cover" can be defined as the layer of leaves, branches, and stems of trees and shrubs and the leaves of grasses that cover the ground when viewed from above (Sexton et al., 2013). The term "green cover" is typically used to refer to green spaces identified from aerial data, as it is in this study. Green cover is an essential infrastructure in cities because it provides various products and ecosystem services for urban dwellers that can address support climate-change mitigation and adaptation, human health and well-being, biodiversity conservation, and disaster risk reduction (Salbitano et al., 2016). Studies conducted around the world have shown that green cover, particularly trees in urban forests and parks, can address climate-change mitigation and adaptation by filtering polluted air (Selmi et al., 2016), and sequestering atmospheric CO_2 (Tang et al., 2016; Nowak et al., 2013). They can also impound storm water to reduce flash floods and other disasters (Berland et al., 2017; Kok et al., 2016; Salbitano et al., 2016). Not only can large urban forests and parks increase the cooling effect of green spaces (Bao et a, 2016; Jaganmohan et al., 2016), but even small parks in cities were found to have a valuable cooling effect that can assist in mitigating urban heat island effects (Oliveira et al., 2014). Trees planted near buildings can reduce energy use and contribute to low-carbon emissions in cities (Zhang et al., 2014). Moreover, well-designed and managed urban parks and recreational forests can ensure social well-being of urban dwellers by promoting public health and social interaction (Donovan, 2017; Foo, 2016; Wolch et al., 2014). Urban green covers, particularly protected areas such as urban forest and parks, can support local wildlife and biodiversity while conserving natural resources (Threlfall et al., 2017; Karuppanan et al., 2014). Urban forests and street trees are also found to increase property values and attract business investment (Siriwardena et al., 2016). Collectively, urban green cover can significantly contribute to achieving the Sustainable Development Goals set by the United Nations. In accord with these findings, cities around the world have started to integrate green cover in city planning,

especially with the increased focus on urban climate change mitigation due to a projected rise in urban population (United Nations, 2015b).

Kuala Lumpur (KL) is the largest city in Malaysia, and its population is expected to increase from 1.4 million in 2000 to 2.2 million by the year 2020 (KLCH, 2004). The decrease in open space and unprecedented increase in the population density caused the total green space per capita to decrease from 13m^2 in 2010 to just 8.5 m^2 in 2014 (Figure 1). This has fallen below the minimum target of 9 m^2 set by the World Health Organization (WHO), which has also set an ideal value of 50 m^2 per capita (World Health Organization, 2010). From Figure 1 it is clear that KL will not achieve its target of 20 m^2 per capita if the total land allocated for public parks and recreational areas is not proportionate to population growth. Like many other rapidly developing cities around the world, KL has experienced high losses of green cover since the 1980s (Teh, 1989; Webb, 1998), and further losses are expected as an expanding urban population consumes more green space (KLCH, 2004). Strong population growth causes vacant lands and other green spaces, including parks and forests, to be converted to housing and commercial development (KLCH, 2004). Yet the federal government has established the Klang Valley[1] as one of its main regions to be developed under the National Transformation Program (NTP), which aims to transform Malaysia into a developed country by 2020. Various programs have been put forward to improve this region's physical environment to attract foreign investments, increase its population and create more job opportunities (PEMANDU, 2013). Urban greening is one of the important agenda items under the program to transform KL into one of the top-twenty most liveable cities in the world by 2020.

[Insert Figure 1 Here]

In order to reduce the drastic loss of green space i.e. forests, state governments in Malaysia are empowered to reserve (gazette) any urban forest under the National Forestry Act of 1984 (sections 7 and 10). Similarly, any state land can be gazetted for any public purpose under local laws (National Land Code 1965 (Under Section 62 (3) and 14). Once a forest or open space is gazetted, any intrusion or development in the area is prohibited and punishable except under the authority of a licence. However, the laws are structured to stop petty incursions on forests, but not to protect against large-scale destruction (Kathirithamby-Wells, 2005). Consequently, green cover—including the gazetted areas—experience threats from intensive urban development in Malaysia (Teh, 1989; Webb, 1998; Curren, 2004).

[1] Klang valley is an area covering 2793.27 km^2 that encompasses the federal territories of KL and Putrajaya, and ten municipalities in the nearby state of Selangor.

Therefore, there is a need to monitor the changes in green coverage, particularly within protected areas, in order to assess the current condition of urban green space. It is also important to set goals to create an effective management plan that can account for biological diversity, ecosystem stability and human well-being. Although urban green cover is constantly changing, not many studies have quantified the amount of green cover and its overall change (Nowak et al., 2012, Schäffler and Swilling, 2013; Hall, 2010; Brunner and Cozens, 2013; Kabisch and Haase, 2013). Thus, there is a need for more knowledge on changes in the quantity of urban green cover. In Malaysia, high-resolution aerial photographs were used by Teh (1989) to map green cover in and around KL, concluding that a vast amount of green area was lost to commercial and residential areas since 1980. Meanwhile, Webb (1998) reported the loss of urban forests in KL, and Tan et al (2010) found a decreasing trend in forest cover in the island of Penang. In a recent study, Kanniah and Siong (2017) show that over a period of 12 years (2000-2012), four major cities in Peninsular Malaysia lost between 4 and 17 % of tree cover from their total land area. Other studies related to urban green space in Malaysia investigate green-space policy (Abdul Aziz et al., 2011), the ecology and social benefits of urban green space (Baharuddin et al., 2014; Karuppannan et al., 2014; Foo, 2016), household contribution to urban greening (Barau, 2015), and fear of crime in urban areas (Sreetheran and Konijnendijk, 2015). Monitoring green cover in the urban environment can be done effectively using remote sensing data from earth-observing satellites that enable the extraction of spatial information over regular intervals and long periods of time. The aim of this study was to monitor green cover changes in Kuala Lumpur using satellite data. The study seeks to answer the following research questions:

1. How much has green cover changed over time in KL?
2. To what extent do gazetted area policies prevent green cover loss in KL?
3. What are the challenges in protecting green cover?
4. What are the strategies to increase green cover in KL?

2. Data and Methodology

2.1Study area

Kuala Lumpur (KL), the capital city of Malaysia, is located in Peninsular Malaysia, approximately 320 km from Singapore to the south and 1200 km from Bangkok, Thailand to the north (Figure 2). It covers an area of 243 km^2 and is governed by Kuala Lumpur City Hall (KLCH). Under the KL Structure Plan (2004–2020), the city is divided into six strategic zones (Figure 2) that aim to develop KL in a sustainable way by focusing on land-use distribution, new growth areas,

infrastructure development and environmental sustainability (KLCH, 2004). KL is composed by various land uses that are typical of a metropolitan city, including residential, commercial, industrial, institutional, infrastructure, and green spaces (KLCH, 2004). Prominent green spaces in KL include four permanent reserved forests, recreational forest parks, and other urban and neighborhood parks (KLSP 2000). Like many urban centers, KL continues to experience strong population growth which increases demand for land. A vast amount of green space has already been replaced by grey infrastructure (Teh, 1989; Webb, 1998). This study is restricted to the municipal area of KL because it allows making recommendations specific to the municipality.

[Insert Figure 2 Here]

2.2 Data and methods

2.2.1 Remote sensing data

In this study, Kuala Lumpur's urban green cover and its changes between 2001 and 2016 were monitored using satellite images. Four scenes (path 127 and row 58) of Landsat Thematic Mapper (TM) and Operational Land Imager (OLI) data were downloaded from the United States Geological Survey (USGS) website (USGS Earth Explorer, 2016). Landsat satellite images with 30-m spatial resolution were used in this study. The Landsat program provides images dating back to 1972, enabling observation of changes in urban vegetation over long time periods. These data are geo-referenced by the data provider and also available for free, which makes them preferable for mapping areas as large as the city of KL.

The images used in this study cover 12 September 2001 (TM), 22 April 2013, 8 March 2014, and 25 January 2016 (OLI). These periods were selected to observe the changes in green cover before and after implementation of the "Greening KL" program, which was aimed to plant 100,000 trees by year 2020. The National Transformation Program (NTP) launched in 2010, focuses on 12 National Key Economic Areas (NKEA) and one of them is Greater KL/Klang Valley. Under the Greater KL/Klang Valley NKEA, nine entry point projects (EPPs) were created. EPP 6 is concerned with greening the Greater KL/Klang Valley to ensure residents enjoy sufficient green space based on WHO recommendations. These satellite images were selected to exclude any major cloud coverage (images of KL with cloud coverage of only 5% or less were selected in the analysis).

The images were processed using the Carnegie Landsat Analysis System-algorithm (CLASlite-version 3.3). CLASlite is a computer program written to detect forest cover, deforestation and

disturbance mainly in tropical regions using satellite images (Asner et al, 2009). However, in this study the default threshold values that are typically used to detect forest tree cover were modified to detect urban tree and green covers. CLASlite was also used to (i) correct all four Landsat images used in this study for atmospheric distortion, (ii) calibrate raw digital numbers of satellite data to reflectance values, and (iii) mask out clouds, cloud shadows and water bodies.

2.2.2 Remote sensing data processing

Since the 30-m spatial resolution of Landsat sensors may produce lower mapping accuracies compared to high spatial resolution commercial data such as GeoEye, especially in urban areas, a spectral unmixing technique commonly used for land cover extraction at medium-resolution remote sensing data was employed in this study. Each pixel of the Landsat images (30 m x 30 m) was unmixed into fractional cover using the Automated Monte Carlo Unmixing (AutoMCU) model embedded in CLASlite (Asner et al., 2009). This technique de-convolves each pixel into fractional abundances of photosynthetic vegetation (PV), non-photosynthetically active vegetation (NPV) and bare substrate (S). NPV represents the fraction of senescent vegetation associated with dried carbon compounds in dead leaves and exposed wood, whereas bare substrate consists of exposed mineral soil, rocks and human-made infrastructure (Asner et al., 2009). For urban vegetation cover, the detection of bare substrate fractional cover is important because it represents soil, road and other impervious surfaces. The spectral libraries created using extensive fieldwork in tropical forests are used by AutoMCU to classify the images into PV, NPV and S fractional covers (Asner et al., 2009). From the fractional cover images, forest (tree) and non-forest (non-tree) images and green-cover (trees, shrubs and grasses) and non-green-cover images were produced using the following thresholds that were modified from their original values provided in CLASlite:

Green cover: PV $\geq$ 70 S < 25

Tree cover: PV $\geq$ 80 S < 70

The default threshold for forest and non-forest detection as provided in CLASlite is = PV $\geq$ 80 AND S < 15, Non-forest = PV < 80 OR S $\geq$ 15. However, these thresholds were adjusted arbitrarily using a trial-and-error method, and a threshold of less than 70% of S coverage in each pixel enabled the program to detect street trees successfully. Since street trees are surrounded by soil, road and other impervious surfaces, allowance of more S was found to detect street trees with less error compared to another set of 33 combinations with PV ranging between 60% and 80% and S ranging from 5% to 100% attempted in this study. For the detection of green cover, a threshold value of PV $\geq$ 70 S < 25 could possibly detect all vegetation types (grass, shrub and trees).

The tree and green cover results obtained from CLASlite technique were validated for accuracy using another independent set of green/tree data from Google Earth. Polygons (89 polygons with 9 pixels in each polygon for green cover and 78 polygons with 8 pixels in each polygon for tree cover) distributed across KL were considered as ground-truth because these maps were produced from aerial photos and high-resolution satellite data such as Quickbird and has been used for land use/ cover classification and validation (Cracknell et al., 2013; Hu et al., 2013; Yu and Gong, 2012; Kaimaris et al., 2011). In this study Global Positioning System (GPS) coordinates using Geo XT 3000 handheld GPS with 50 cm locational accuracy at thirty locations in KL were collected from 6 to 10 July 2017 to verify ground truth points from Google Earth (Figure 3). The accuracy of the classified satellite images was assessed using confusion matrices and kappa coefficients (Congalton, 1991).

[Insert Figure 3 here]

2.2.3 Structured interview

In order to answer the research questions outlined in Section 1 regarding the role of gazetted areas in reducing green cover loss and the opportunities and challenges of protecting green cover, structured interviews were conducted with a total of nine officers at the following organizations: Kuala Lumpur City Hall (3 officers), National Landscape Department (1), Forestry Department, Federal Territory of KL (1), non-governmental organization (NGO) (1), landscape architects (2), and a private property information technology firm (1). Details of the interviews are shown in Table 1 and the questions asked to the interviewees are tabulated in Table 2.

[Insert Table 1 Here]

[Insert Table 2 Here]

2.2.4 Focus Group Discussion

In addition to interviews, two Focus Group Discussions (FGD) were held with stakeholders involving officers from KLCH, the National Landscape Department, urban planning departments of four municipalities within the Klang Valley Region (Ampang Jaya, Klang, Subang Jaya, and Selayang municipalities), NGOs (dealing with environmental related issues), a local university and private companies (Table 3). Twenty stakeholders were invited to participate in FGD 1 and 15 accepted, while 16 stakeholders were invited to participate in FGD 2 and 7 accepted. The officers were selected based on their knowledge and experience working with issues related to the environment, particularly on green space in the Kuala Lumpur/Klang Valley region. The first FGD was held on 21 August 2016, with the objective to find out if KL has enough green space (according to WHO standards), how much green space is needed to sustain the increasing

population, and what opportunities exist to increase green space in KL. The second FGD was held on 27 February 2017. The second FGD was aimed at discussing and ranking actions and measures (based on their significance, suitability and feasibility) to protect and increase green cover that were identified in the satellite data analysis, FGD 1, and the interviews. New suggestions to protect or increase green cover in KL were also obtained from the stakeholders. The recommendations are listed (section 5) in order of importance as expressed by the FGD 2 participants. Results from the FGDs and interviews were analyzed qualitatively by separating the stakeholders' responses based on the research questions. The overall methods adopted to answer the research questions of this study are shown in Figure 4.

[Insert Table 3 Here]
[Insert Figure 4 Here]

3. Results and discussions

3.1 Validation of Google Earth and green cover obtained from satellite images

Several notable merits of Google Earth for global scale research are extensively discussed by Yu and Gong (2012). An important merit highlighted by Yu and Gong (2012) is the use of freely available remotely sensed images that provide base map and/or validation for research in urban studies (page 3975). The positional accuracy of Google Earth data is 40 m root mean square error (RMSE) worldwide and about 24 m RMSE in more developed countries (Potere, 2008). A local validation in Texas, USA (Benker et al., 2011) using high precision (<1 m) field measurements show an accuracy of 2.64 m RMSE (horizontal) and 1.63 m RMSE (vertical). In this study the author compared virtually traced positions in Google Earth such as road junctions, petrol stations, etc. against the GPS measurements and computed the RMS errors. The RMSE of both northing and easting are 7.57 and 4.25 m respectively (data not shown). Thus, Google Earth data were used for assessing the accuracy of green and tree covers extracted from Landsat images.

A summary of classification accuracy—producer, user, overall accuracies and the kappa coefficient[2]—is shown in Table 4. The producer, user and overall accuracy of the classified Landsat images are greater than 90% for both green and tree cover detection. These results mean the producer of this classification can reasonably claim that more than 90% of the areas classified as

[2] Producer accuracy (PA) A = number of correct pixels in one class ÷ total number of pixels as derived from reference data.
User accuracy (UA) = correctly classified pixels in a class ÷ total number of pixels that were classified in that class.
Overall accuracy = ccorrectly classified pixels in each class ÷ total number of pixels checked
Kappa coefficient = coefficient of agreement between classified image data and ground reference data. Kappa value of 0 means no agreement between image map and ground reference, whereas Kappa of 1 means a complete agreement between the two data sets
Source: Banko (1998)

green and forest cover were identified as such (Lillisand and Kiefer, 2004). The kappa statistics are between 80% and 94% (Table 4), indicating that an observed classification is 80–94% better than one resulting from chance (Lillisand and Kiefer, 2004). Since the accuracy of CLASlite-obtained green and tree cover is high, the data was used for further analysis to detect the total area and its change over time in KL.

[Insert Table 4 Here]

The accuracy of CLASlite results was also assessed by visually comparing the results with Google Earth images and green cover classified by per-pixel image classification technique (Maximum Likelihood Classifier data not shown), especially to assess CLASlite's capability to extract linear green features in KL (Figure 5). Richards et al. (2017) reported that the pixel-based classification techniques failed to delineate linear green corridors, street trees and smaller patches of vegetation. However, using a sub-pixel classification technique, CLASlite is able to extract linear green cover successfully (Figure 5).

[Insert Figure 5 Here]

3.2 Overall green cover detection in KL and its change from 2001-2016

The total coverage of green in KL for 2001, 2013, 2014 and 2016 are shown in Figure 6a and Table 5. The total green coverage of 6,575 ha (27% of KL's land area) in 2001 fell to 5,900 ha (24%) by 2013. However, the trend reversed thereafter, showing 7,362 ha in 2016, or 30% of KL's land area (Figure 6a). The spatial patterns of change (gain and loss of green cover) are shown in Figure 6b. The loss is represented in red and the gain of green cover is shown in blue. A net loss of 3% occurred from 2001 to 2013. Most of the losses occurred in the northwest, northeast, and west sections of the city and near the city center, covering the Sentul Menjalara, Damansara Penchala and Wangsa Maju Maluri zones (see Figure 2). However, green cover started to increase from 2013 with most of the increase contributed by trees planted along the streets and at other locations, mainly in the Damansara-Penchala zone and city center (Figure 6b and Figure 2). There is a small decrease of 1% in tree cover between 2013 and 2014. This pattern can be explained by the trees newly planted since 2011 that could have been detected as shrubs by satellite sensor. A more specific analysis of tree cover data (Table 5) shows that 60% of the increase was contributed by trees planted along the streets and at other locations such as in recreational parks and forests.

[Insert Figure 6 Here]

[Insert Table 5 Here]

One of the contributing factors to the increase in urban green cover since 2013 can be associated with the "Greening Greater KL" program launched in 2011 under the federal government's National Transformation Program (PEMANDU, 2014). As part of efforts to transform Kuala Lumpur (KL) into a world-class liveable city by 2020, the Kuala Lumpur City Hall (KLCH) aimed to increase green cover by planting 100,000 large-canopy trees by 2020 (PEMANDU, 2015). KLCH supports this initiative by working with the private sector, which sponsors tree-planting and park establishment within KL. KLCH planted almost 200,000 large-canopy trees (including. *Hopea odorata (Merawan Siput), Samanea saman (rain tree), Diospyros pilosanthera (Kayu arang), Swietenia macrophylla (big leaf mahogany*) and others) between 2011 and 2016, exceeding its target (interview with deputy director, Landscape section, KLCH). In addition to tree planting through the "Greening Greater KL" program, various efforts undertaken by KLCH to increase green cover in KL (documented in the KL Structure Plan 2020, KL City Plan and KL Landscape Master Plan) include gazetting parks (recreational, urban, neighborhood and local parks and football fields, developing pocket parks (section 3.5.2) and connecting green patches.

3.3 Changes in gazetted green space

Analysis of the time series (Figure 6) shows that two of the gazetted public parks (Kepong Metropolitan Park (Figure 7a) and Pudu Ulu Recreational Park (Figure 7b) lost 9% (13.69 ha in total) of their green areas in just two years. Additionally, Landsat satellite images between 2014 and 2016 detected the loss of 23.88 ha of forest areas located near the Sungai Besi Permanent Forest Reserve (Figure 8a) and 11.06 ha in Bukit Gasing Reserve Forest (Figure 8b), signifying a loss of 7.2% (Figures 6b and 8). Overall, 24.5 ha of gazetted public open space and recreation area in KL were lost from 2015 to 2016 (personal communication, Department of Town and Country Planning, Peninsular Malaysia). The city center of KL also witnessed green cover loss of 0.6% compared to the total land area (1,819 ha) between 2014 and 2016 (Table 6).

[Insert Table 6 Here]
[Insert Figure 7 Here]
[Insert Figure 8 Here]

Overall, the results of this study show an increase in green coverage from 2014 to 2016. However, there has still been a significant decrease in open space and recreational areas in Kuala Lumpur (KLCH, 2004). Most of these spaces are gazetted and thus legally protected from development. Nevertheless, legal protection of green space has not prevented development from encroaching into

these areas. According to the Department of Town and Country Planning, Peninsular Malaysia (2016), 45% of 2,184 ha total of public open space and recreational land in KL, is gazetted. A visit by the author to Kepong Metropolitan Park found that a small portion of the park has been cleared (Figure 7a) to build affordable housing for the ever-increasing population in KL. Kepong Metropolitan Park, which covers an area of 127 ha, has been converted from a mining site. Almost half of the park is still covered by a lake as a remnant of the mining process, creating a habitat for 14 different bird species (Baharuddin et al., 2010). Eight of the species are protected species, and two are rarely found at other parks (Baharuddin et al., 2014). However, the later Baharuddin study identified only 10 species in Kepong Metropolitan Park in 2014; and neither of the rare species was found. (Strange, 2000 in Baharuddin et al., 2014). If uncontrolled development continues in the park, its ecological significance may disappear. Similarly, part of Pudu Ulu Recreational Park has been cleared (Figure 7b) and the author's July 2017 visit to the park found that the area has been planted with small trees, a water fountain and tiled floor have been built for recreational activities.

3.4 Lack of Protection for Kuala Lumpur's green cover

Although the stated importance of green cover within urban areas in Malaysia is evident in national programs such as "Greening Greater KL," the loss of green cover remains significant. Several policies and guidelines have been formulated by various agencies to guide green cover planning and management. However, responses obtained from the FGDs (particularly information from participants from NGOs) and interviews revealed that green spaces are not fully protected because no clear regulations and enforcement are available to protect them. For example, the National Urbanisation Policy, formulated by the Department of Town and Country Planning, Peninsular Malaysia, provides measures to conserve environmentally sensitive areas (Policy 8) and adopts a target of 20 m^2 of open space per capita (Policy 9(ii)). The policy also calls for recreational areas to be gazetted and environmentally sensitive areas to be protected. Another important policy by the Department of Town and Country Planning is the public open space policy that calls for a minimum of 10% public open space in every housing scheme. The recently formulated National Landscape Policy, developed by the National Landscape Department in 2011, outlines 74 action plans to transform Malaysia into a "beautiful garden nation" by 2020 (National Landscape Department, 2011). Actions 2.1.1, 3.1.5, 3.1.6, 3.1.8, 4.1.1, and 6.11-6.17 in particular specify imposing a minimum of 30% greenery in urban development projects, gazetting all public parks and open spaces, encouraging vertical gardening, and re-evaluating and formulating legislations related to landscape. However, the policy is merely a guideline; in practice, implementation varies among local authorities and each state (Ibrahim et al., 2013). These policies also lack strong enforcement

mechanisms for protecting green areas. Moreover, the National Land Code in section 64 (1) allows revocation of reserved and protected public parks and recreational areas by the public actors. Consequently, due to development pressure, even gazetted land can sometimes be converted to more economically valuable land uses such as housing. Informants interviewed in this study mentioned that some green spaces such as local play areas and neighbourhood parks are not gazetted at all and lack any obstacles to conversion to other land uses.

The only act directly related to preservation and planting of trees in KL is the "Tree Preservation Order" under the Federal Territory (Planning) Act, 1982. Section 36 of this act states that large trees with a girth exceeding one meter must be preserved and felling them without permission is an offense worthy of a fine of not more than RM 5,000 (~USD 1,200). Trees and other greenery found in public parks in KL are also protected under the 1981 Parks (Federal Territory) By- Laws of the 1976 Local Government Act. Although these by-laws state how trees should be preserved and protected from physical damages, it is not easy to implement the by-laws because basic data of tree inventory is not available. Therefore, it is difficult to prove the existence or disappearance of trees in a particular location. Informants emphasized that a comprehensive database of existing green cover (location, type, size, species, health condition, percentage tree cover, gap sites etc.) is essential not only for protection of the resource, but also for green cover planning and management With more complete and comprehensive datasets, enforcement of the "Tree Preservation Order" may become possible in the future (Tan et al, 2013). KLCH has only recently started to inventory and tag the geolocations of newly-planted trees under the "Greening Greater KL Program." Since 2014, a total of 85,000 trees have been tagged (PEMANDU, 2014).

The National Forestry Act 1984 is another important piece of legislation which applies to forests located within the cities. This act empowers the state government to constitute any land as a permanent reserved forest (Section 7). Once the forest has been gazetted as a permanent reserved forest, various forms of protection can be given to the forest (Mustafa, 2009). However, when conflict occurs between economic development and environmental protection, economic development supersedes: it is legal to cut down forests (Section 11) if the land will be used for building something of higher economic value than the forests' current use (section 10). The absolute legal priority of economic development is a major barrier to protecting urban forests in Malaysia. Sometimes the loss of green areas to developments appears to be a political issue involving multiple levels of government, which is difficult for the local authorities to control (Tan et al, 2013).

Despite the extent of green policies and legislation, informants mentioned that lack of coordination between different government agencies is another reason for poor implementation and enforcement in KL. Responsibility for management of green cover that is currently spread across the Physical Planning, Landscape and Recreation, and Environmental Health departments of KLCH, the Federal Territory Department of Forestry, the Department of Land and Mineral, Federal Territory and Department of Town and Country Planning should be integrated under one unit. This unit should be responsible for the planning, monitoring and management of all publically and privately owned green spaces in KL. In Europe, greenspace responsibilities are typically placed under the Public Parks or Engineering departments (Randrup and Persson, 2009). In Singapore and Hong Kong promoting greening policies and programs within national and urban developmental plans is coordinated under a single institution called National Parks Board and Greening, Landscape and Tree Management section respectively (Tan, 2016). In Johannesburg, South Africa fragmented park services were reorganized into a single agency called City Parks to ensure common standards are applied across the city (Salbitano et al., 2016). KL would benefit from a similar organizational model because tight coordination between various government agencies would render fast and efficient service delivery process.

3.5 Recommendations to protect and increase green cover in Kuala Lumpur

3.5.1 Gazette more forests for enhanced ecosystem services

Identifying and protecting more ecological assets like forest areas as permanent forest reserve (PFR) is essential to increase green cover in cities. PFR in KL had diminished about 50% since they were gazetted in the early 20th century (Webb, 1999). Currently there are 4 PFRs (Figure 9) that covers 0.3% (69 ha) of Kuala Lumpur's land mass. These forests are capable of contributing to a total carbon storage of 40.02 ktCO_2 by 2030 (Kuala Lumpur Low Carbon Society Interim Report, unpublished) and provide goods and ecosystem services worth of USD 403,000 per hectare (unpublished report, FTFD). Conservation of these forests is therefore important to preserve their function as a carbon reservoir and cool refuge within a warm city. The Federal Territory Forestry Department (FTFD) has proposed to the federal government to gazette two areas of 50 ha in total near Sungai Besi Forest Reserve (Figure 9) as permanent reserve forest (interview with Director of FTFD). Participants of the second FGD suggested that Bukit Gasing (secondary forest with 153.6 ha), Bukit Kiara (forest park with 188.9 ha) and other forests shown in Figure 8 also be protected. These forests are not only important carbon reservoirs, but they are also preferred by local communities for recreational activities such as hiking. A recent study by Foo (2016) found that forests in the Klang Valley region strongly contribute to the quality of urban dwellers' life.

However, these forests have been seriously degraded for development in the Klang Valley region (Foo, 2016).

[Insert Figure 9 here]

3.5.2 Convert vacant land into pocket parks

Participants of FGD 1 and KLCH officers that were interviewed believe that another strategy to protect green space is to upgrade open spaces and vacant lands into pocket parks, or to assemble several such parcels into larger public parks. These public parks should be gazetted before they are lost to development projects as they are actively utilized by local residents for various recreational activities (Sreetheran, 2017). Although large parks can provide more amenities to users, small, scattered pocket parks are convenient in KL, which lacks space for large parks (currently ~39% of the city is composed of concrete urban surface). Approximately 4% of vacant land identified in KL can be considered for pocket parks (unpublished data-manuscript in preparation). Pocket parks can also be developed on block corners, between blocks, and in areas of heavy pedestrian traffic that are convenient to pass through. FGD 1 participants suggest that KLCH should plan to create more pocket parks at every Light Rail Transit (LRT) station in KL. Currently there are six pocket parks[3] in the city center of Kuala Lumpur, which are primarily upkept and maintained by private companies such as financial instituitions and property developers. Throughout the world, pocket parks serve local needs for resting, socializing or just passing through, as has been observed in Copenhagen (Peschardt et al., 2012) or for promoting physical activities, as has been practised in Los Angles (Cohen et al., 2014). One of the pocket parks located in the city center of KL, Laman Standard Chartered (maintained by Standard Chartered Bank), accommodates 120 native *Hopea odorata* trees , locally known as *merawan siput jantan*, in the park and provide a shaded resting area for passers-by.

3.5.3 Set tree canopy cover target

Although KLCH achieved the "Greening KL Program" target of 100,000 trees added by end of 2016, this study proposes setting a new target of 30% tree canopy as the program continues in the coming years. Trees can bring multiple benefits to the city like providing attractive views of urban

[3] Pocket parks in Kuala Lumpur (Source: Landscape section, KLCH)
(i) Laman Std Chartered KL (P. Ramlee Road) by Standard Chartered Bank
(ii) Laman EcoSky (Ipoh Road) by Ecosky Property developer
(iii) Laman Veritas (located between P. Ramlee and Ampang Roads) by Veritas Architectural Company
(iv) Taman Tasik Sri Murni by JL 99 property developer
(v) Taman Bukit Kerinchi by IJM Land-property developer
(vi) Air Terjun Country Height (Junction of Tun Perak and Raja Laut Roads) by Think City property developer

greenery, and trees planted along streets can provide shading that can promote walkable communities. Setting tree canopy cover targets as a means to increase urban green cover is advantageous because it is much easier to monitor the spatial and temporal change in tree cover (using aerial data) compared to monitoring tree cover by individually counting trees. Based on the tree canopy cover data extracted from satellite images in the present study (Figure 6a and Table 5), the tree canopy cover of KL is only 17% of its land area. As a point of local comparison, in Singapore the vegetation cover as obtained from aerial images was 40% of its land area in 2011 (Tan, 2016). The non-profit organization American Forests recommends tree coverage of between 40–60% in forested states in U.S.A as an amount that can keep the temperatures low, keep the air clean and provide extremely effective onsite storm water management (American Forests, 2017). The city of Melbourne, Australia has set a target of 40% tree cover by the year 2040 (City of Melbourne, 2011), while London has set a goal to increase its green cover to 30% by 2050 as a way to buffer the city from floods and hot weather (Salbitano et al., 2016). A recent study in the U.S. has confirmed that property values are maximized at about 38% tree cover at county-level and 30% at property level (Siriwardena et al., 2016). It is recognized that these targets vary across different climatic and ecosystem conditions, and that the optimal canopy cover target depends on the ecological, economic and social services provided by the trees, their cost, and community desire. Based on the above studies, it is recommended that KLCH set a target of 30% tree canopy cover and plan strategically to increase tree cover (including roof top planting). Participants of the second FGD, particularly those from NGOs, strongly agreed with this suggestion and proposed protecting other recreational forests and trees in public parks and housing areas to achieve 30% tree cover in KL.

Different tree canopy covers target can be set based on locations. Locations with less tree cover should be set higher target than locations with more tree cover. Measurements of current tree canopy cover and surface temperature are required so that tree planting activities can be well-designed. These targets can also support tree planning in locations with high surface temperature or highly polluted air. With the detection of the current tree canopy cover in KL (Figure 6a), a comprehensive plan to increase tree canopy cover in each zone can be strategized. A matrix of canopy cover over development area should be introduced by KLCH to ensure any development within the zone with less canopy cover have higher green elements in the development. For example, a higher requirement on total canopy cover for new developments should be implemented in Sentul-Menjalara area (Figure 2), which currently has the least canopy cover among the six zones in KL.

The types and species of trees that are selected for these locations are also important. The use of native tree species in urban environment is significant due to the greater biodiversity benefits and wider environmental services (Subiakto et al., 2016) and lower risk of native species compared to exotic trees (Sreetheran et al., 2006). KLCH prefers indigenous tree species for street planting, where ~69% of the trees surveyed along five major roads in the city center are dominated by native species such as *Pelthophorum pterocarpum* and *Pterocarpuc indicus* (Sreetheren et al., 2011). Additionally, NGOs such as 'Landscape Malaysia' have planted over 15,000 native trees covering 20 species (from the Shorea, Tristaniopsis, Baccaurea and Syzygium genera) in recreational forests and public parks in Kuala Lumpur. Landscape Malaysia also works closely with property developers to ensure that at least 60% of trees planted in new development areas consist of native tree species (Director, Landscape Malaysia).

The objective of increasing tree cover canopy in KL will only be achieved if KLCH considers employing more certified arborists. Well-trained arborists are crucial for promoting planting, maintenance and management of trees in cities. Two arborists and the former officer of the Performance Management and Delivery Unit of the Malaysia Economic Transformation Program interviewed in this study expressed concern over the lack of arborists in Malaysia and the need for KLCH to invest in more arborists. As of the end of 2016, there are only 90 practising certified arborists in the entire country (compared to more than 400 in Singapore) and only four in KLCH, clearly not sufficient to manage all trees in the city (The Star, 2014, 2016). Poor management of hazardous street trees in KL, for example, poses risk of serious loss to property and life during intense storms (Sreetheren et al., 2011). Therefore, KLCH should employ more certified arborists as a sustainable approach to planning urban forests, determining suitable tree species and the best locations to plant them, performing tree inventories, advising on proper tree pruning, and designing a proper management, monitoring and maintenance system. This will contribute to realizing KL's aspiration to become a garden city by achieving the target tree cover of 30%.

3.5.4 Implement vertical greening on buildings

For cities with limited land like KL, multiple informants suggested incorporating plants into buildings as an attractive strategy. Along with contributing to the city's greenery and storm water management (Kok et al., 2016), rooftop gardens can improve the living quality of urban settlers by reducing air temperature (Tan et al., 2013; Ng et., 2012). Studies conducted in Berlin, Germany showed that greened exterior walls were ~16°C lower in surface temperature during the daytime than bare walls as a result of the shading and transpirational effects of vegetation installed on walls

(Hoelscher et al., 2016). In the tropical environment of Singapore, green walls were found to reduce daytime wall surface temperature up to 10° C (Wong et al., 2010). Implementing vertical greening in buildings in KL will help to reduce surface temperature and provide thermal comfort to residents. In Malaysia, "Roof Top Garden Planning Guidelines" were published by the Town and Country Planning Department of Peninsular Malaysia in 2012. Some cities like Penang, in northern Peninsular Malaysia, have accounted for rooftop gardens in their requirement of 10% public open space applied in every housing scheme, because its development has reached the saturation stage (Department of Town and Country Planning, Peninsular Malaysia, 2011). KLCH can consider introducing a "Green Roof Incentive Scheme," such as those used by the National Parks Board Singapore, to encourage owners of existing buildings to green rooftops in all new development and redevelopment (Centre for Urban Greening and Ecology, 2011). However, urban rooftop gardens must be publicly accessible to be as useful an amenity as parks, and such initiatives are not easily implemented (Tan et al, 2013). Strategies for implementation of the above recommendations follow in Section 3.5.5.

3.5.5 Increase public participation in urban greening

Any efforts to protect and maintain urban green areas depend on public participation. KLCH should adopt a bottom-up approach to consider public needs in green space planning, and inform citizens about the current status of green cover, their greening objectives, and planned initiatives (director, Landscape Malaysia and FGD participants). Examples from other parts of the world illustrate how citizen involvement can support maintenance of green cover (Ruming, 2014). In the city of The Hague in the Netherlands, the "open green policy" enables the public to prepare green space management plans. Public participation in the management of green areas, for example, enabled volunteers to help prepare an inventory of wildlife present in urban green spaces. This effort helped the city to maintain its urban biodiversity (Mabelis and Maksymiuk, 2009). In KL, public participation is not so widespread and occasionally it takes the form of dialogues between KLCH and the public for upgrading existing parks (deputy director, Landscape section, KLCH). Some neighborhood parks (of which there are only five currently) are monitored and maintained by local residents to ensure that the parks can be used safely by the residents. Such initiatives should be extended to more parks and other green spaces. The role of citizens must be further extended to include them in the planning, management, and decision-making processes of urban green spaces. One example of successful participation has been seen in pocket park planning and design in Cairo, Egypt (Noha Ahmed Abd El Aziz, 2017). Such public participation would (i) enhance feelings of ownership among the public over green sites and demand that forest resources should be conserved; (ii) ensure that green cover is better located to meet citizen needs; and (iii) allow urban residents to

participate in forest co-management schemes, including monitoring services, which are shown to improve forest health (Vogt and Fischer, 2016).

KLCH could involve the local residents in collecting tree inventory data to enable enforcement of the "Tree Preservation Order" in KL (section 3.4). Such an open green policy can provide KLCH not only with additional human resources to manage and protect green spaces in KL, but also financial support when government funding for greening efforts has been severely cut. This may be achieved through greening associations' member fees and member donations, and donations from outside sources.

3.5.6 Encourage Public-Private Partnership to protect green cover

Public- private partnership is essential to overcome issues related to finance, resources and capacity in managing and protecting green space in KL (director, Landscape Malaysia). Relying on government to protect or manage the green spaces will not be fully successful as the government itself is limited by its own resources and capacity. The involvement of business actors and civil society organizations as partners in green space management and decision making can greatly assist KLCH to protect urban green spaces in KL. Common forms of financial aid from the private sector, as seen in Europe and the U.S., are taxation initiatives, planning and development opportunities, bonds and commercial finance, income-generating opportunities, and endowments (Gill, 2015). Currently, "adoption of green spaces" and 'community sector involvement' are two common tools used by KLCH to attract funding and material resources.

Smaller green spaces have been adopted under corporate social responsibility programs in KL. The pocket park adopted and upgraded by the Standard Charted Bank, is one of six pocket parks in KL adopted by financial institutions for upgrading and/or maintaining, a practice which could be expanded. Civil Society Organisations (CSOs) such as Landscape Malaysia are contributing to the greening efforts of KLCH by providing and planting trees. From 2009 to 2016, Landscape Malaysia planted 19,000 trees in KL. Although these CSOs provide their own resources for tree planting, KLCH's position as landowner and regulator should be used to monitor and maintain the trees over the long term. Currently, trees planted by NGOs are not maintained well largely due to financial constraints and lack of expertise in KLCH (director of Landscape Malaysia).

Although private companies and CSOs in Malaysia have contributed primarily financially to KLCH's tree planting initiative, their input is still below 20% (Figure 10). More engagements and

partnerships with large private landowners, the corporate sector and CSOs with long-term contractual agreements can be considered by KLCH. For example, agreements with private land owners to plant trees or establish public parks can also help landowners increase their property values. In Lodz, Poland, developing a 600m^2 site into a public park increased the property value and reduced the selling time of a large real estate company (Green Surge, 2016). Where KLCH owns public land, it can also provide vacant land and open spaces to CSOs for greening purposes.

[Insert Figure 10 here]

4. Conclusion

Since green cover provides various ecosystem services and functions to city residents, this invaluable resource must be maintained and well protected. Kuala Lumpur City Hall has taken various efforts to increase urban green cover in Kuala Lumpur. This is evident from the increase in total green coverage (from 24% in 2013 to 30% in 2016) in KL as obtained from the satellite images. Most of the increase was contributed by trees planted at major roads, parks and in recreational forests. Increase in total tree coverage from 15% to 17% (between 2013 and 2016) also reflects the success of public-private partnerships.

Though these findings indicate an increase in total green coverage, Kuala Lumpur also faces continuous loss of green cover (public parks and forest reserves) because of population growth and development pressure. They are not well protected, mainly due to weak enforcement of open/green space policies and the lack of coordination between different agencies and a tree inventory and other green space data. Open space that is accessible to the public for social and recreational activities covers only 9% (2,184 ha) of KL. Therefore, any small reduction in open space can be a major concern to the public. Other green areas in KL include grasses, shrubs and trees found along the roadsides, river reserves, electric lines, rail roads, cemeteries, housing areas, etc. Although green areas constitute almost 30% of KL's municipal area, they are usually not accessible to the public because they are privately owned or not suitable for relaxation and socialising. Although these spaces are not accessible by the public, they still provide other environmental and ecological functions. The government and the public should be aware of the extent and functions of these spaces and protect them by gazetting more green spaces, collecting more data on green cover to enable the enforcement of laws, increasing the role of public and private sectors, and incorporating greenery on buildings. Such approaches are urgently needed before more green spaces disappear

from the city landscape. The loss of green cover may intensify the effect of climate change, adversely affecting KL's image and liveability.

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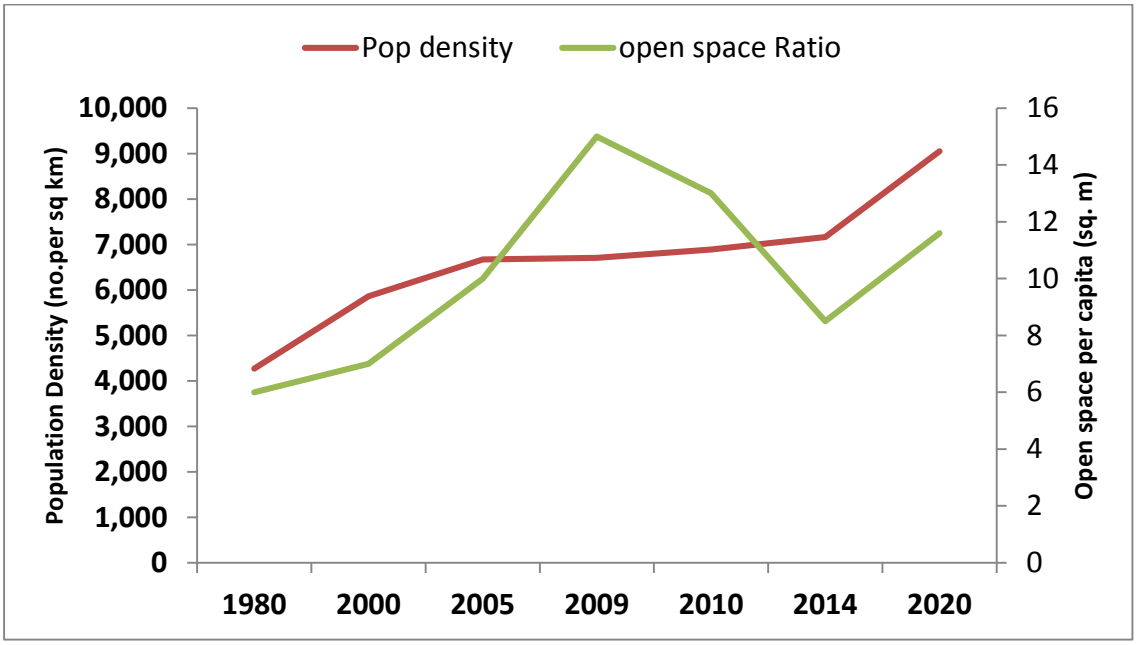


Figure 1

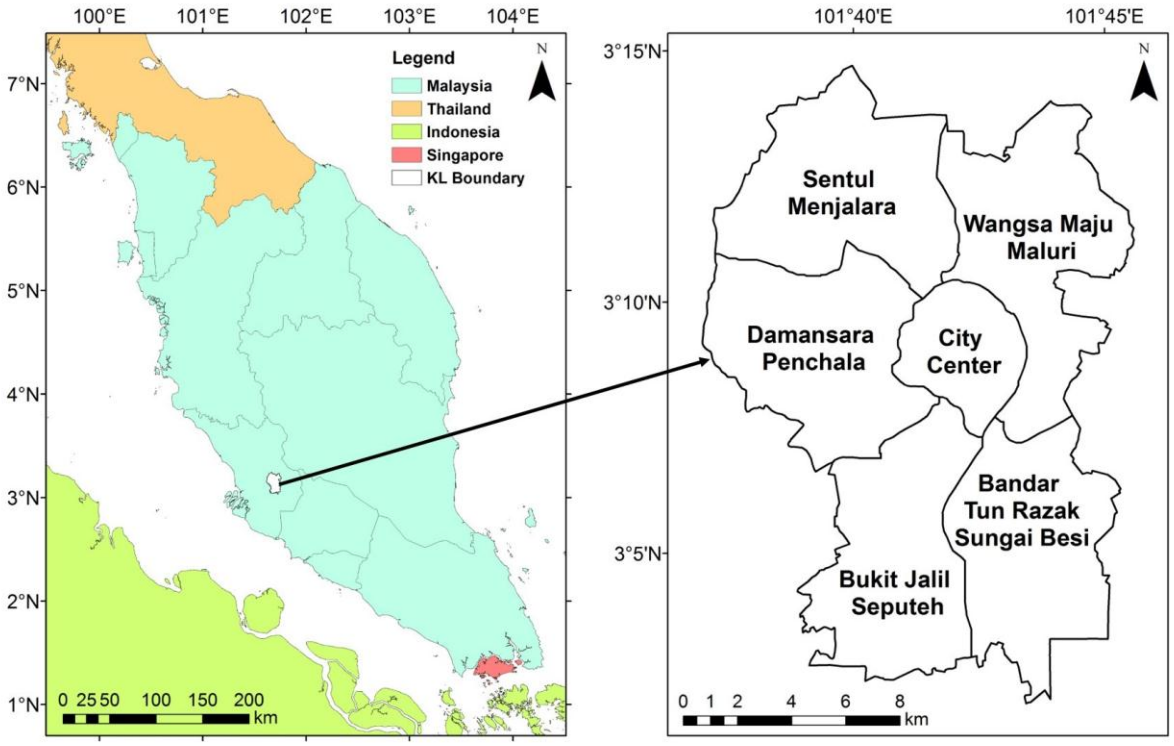
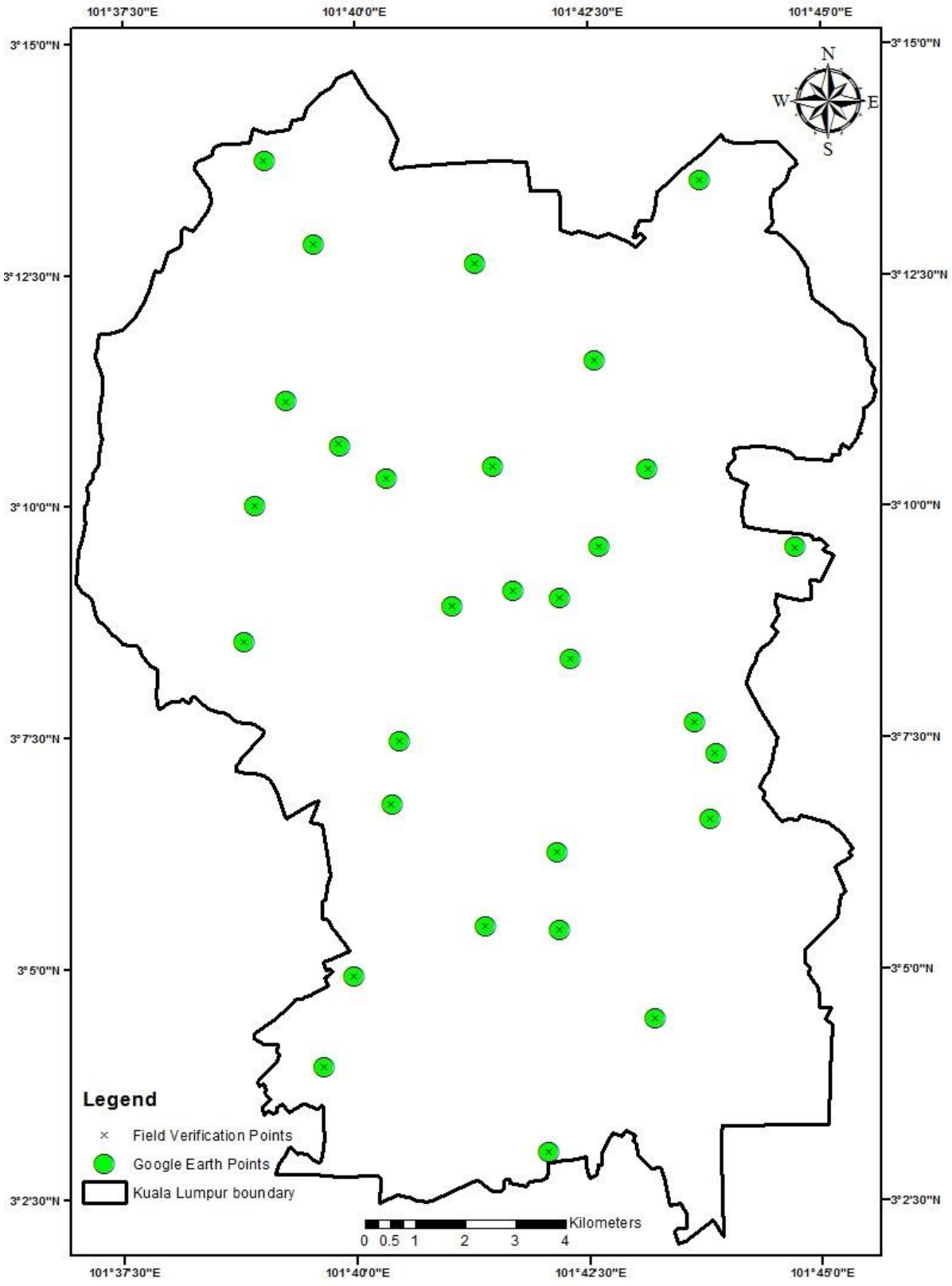


Figure 2



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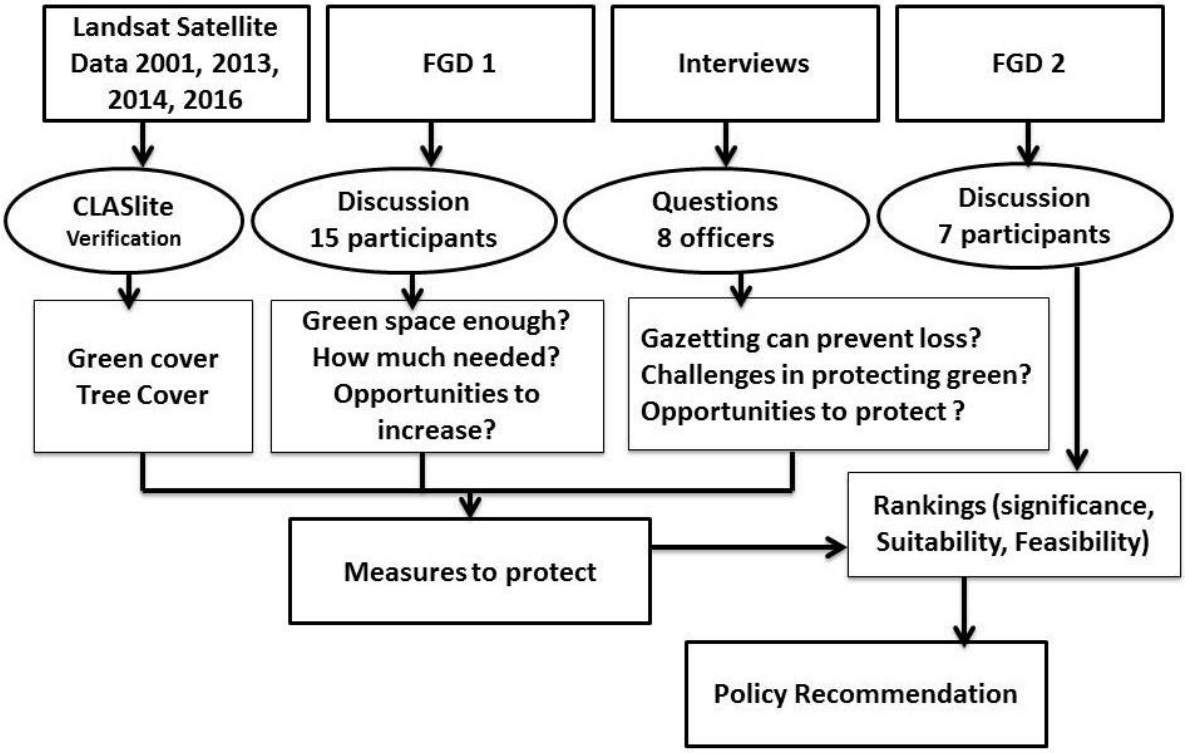

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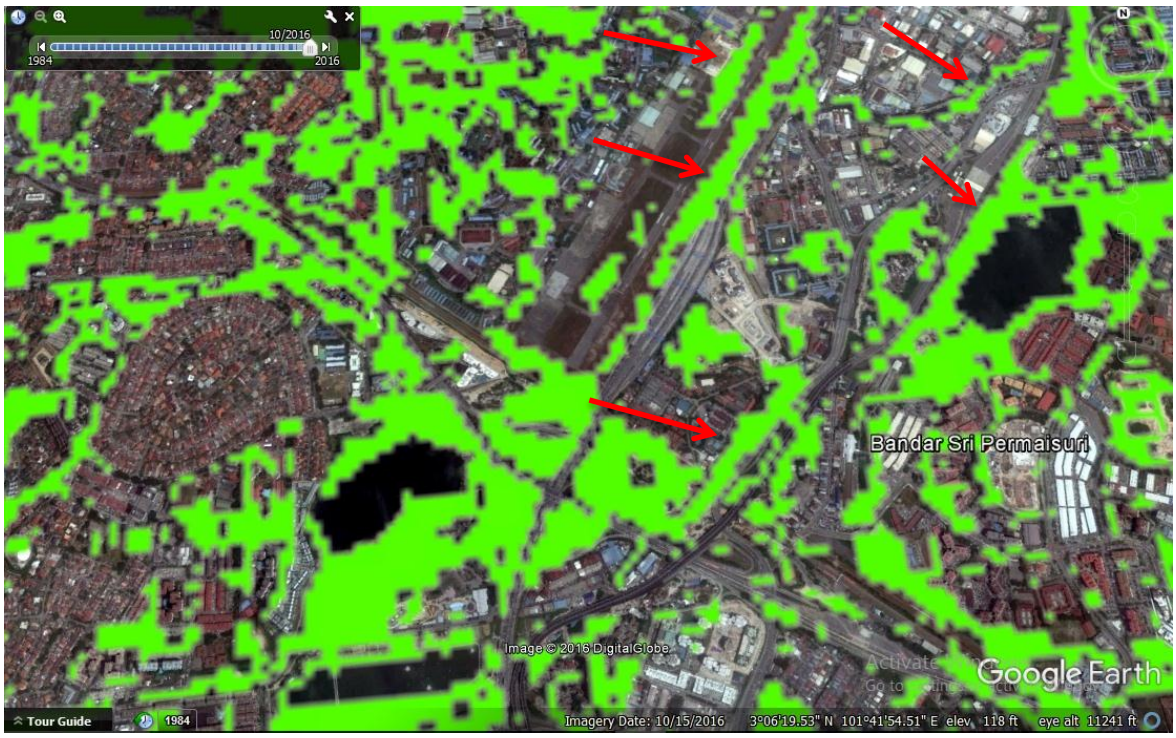
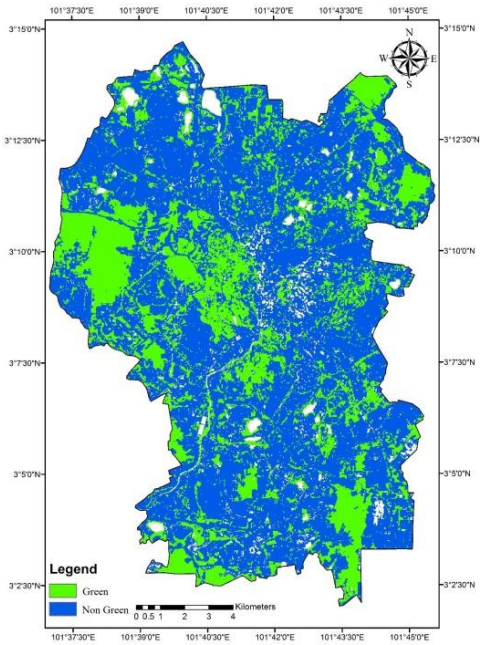


(a)

(b)

Figure 5



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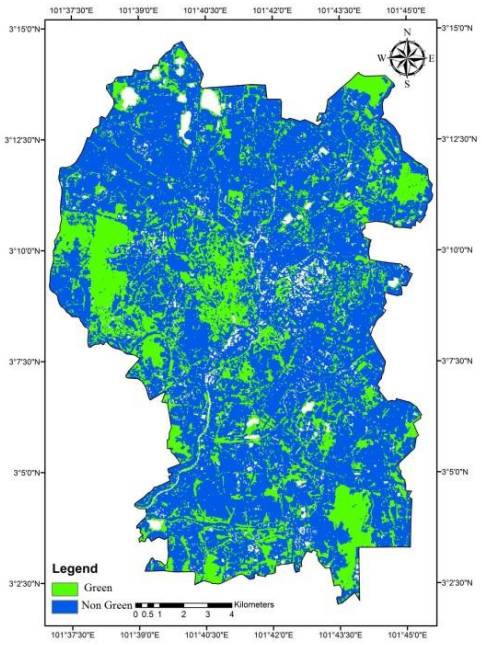

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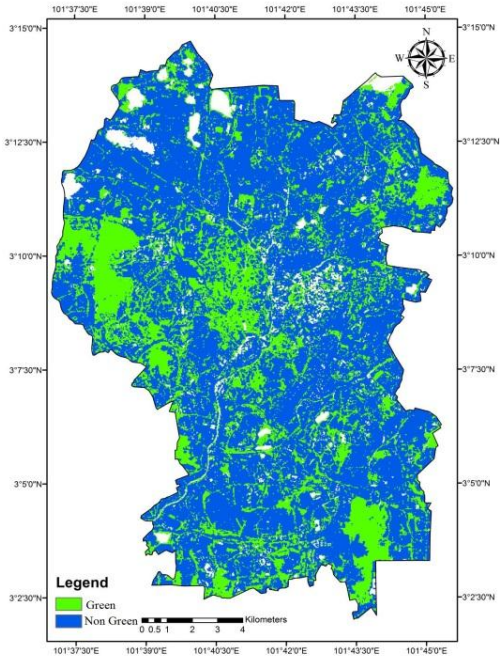

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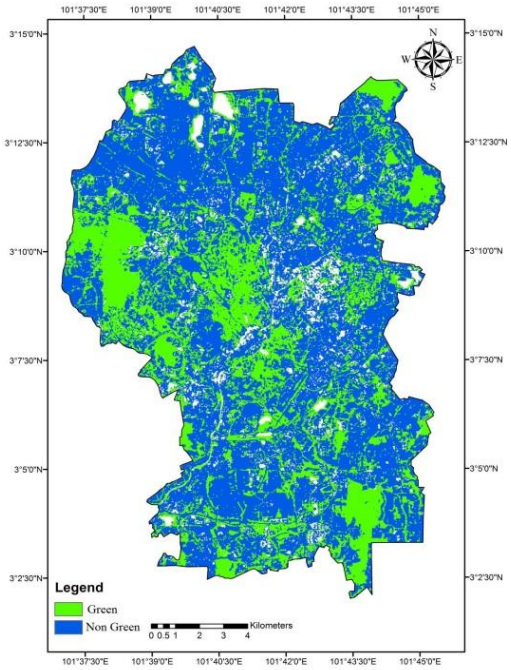
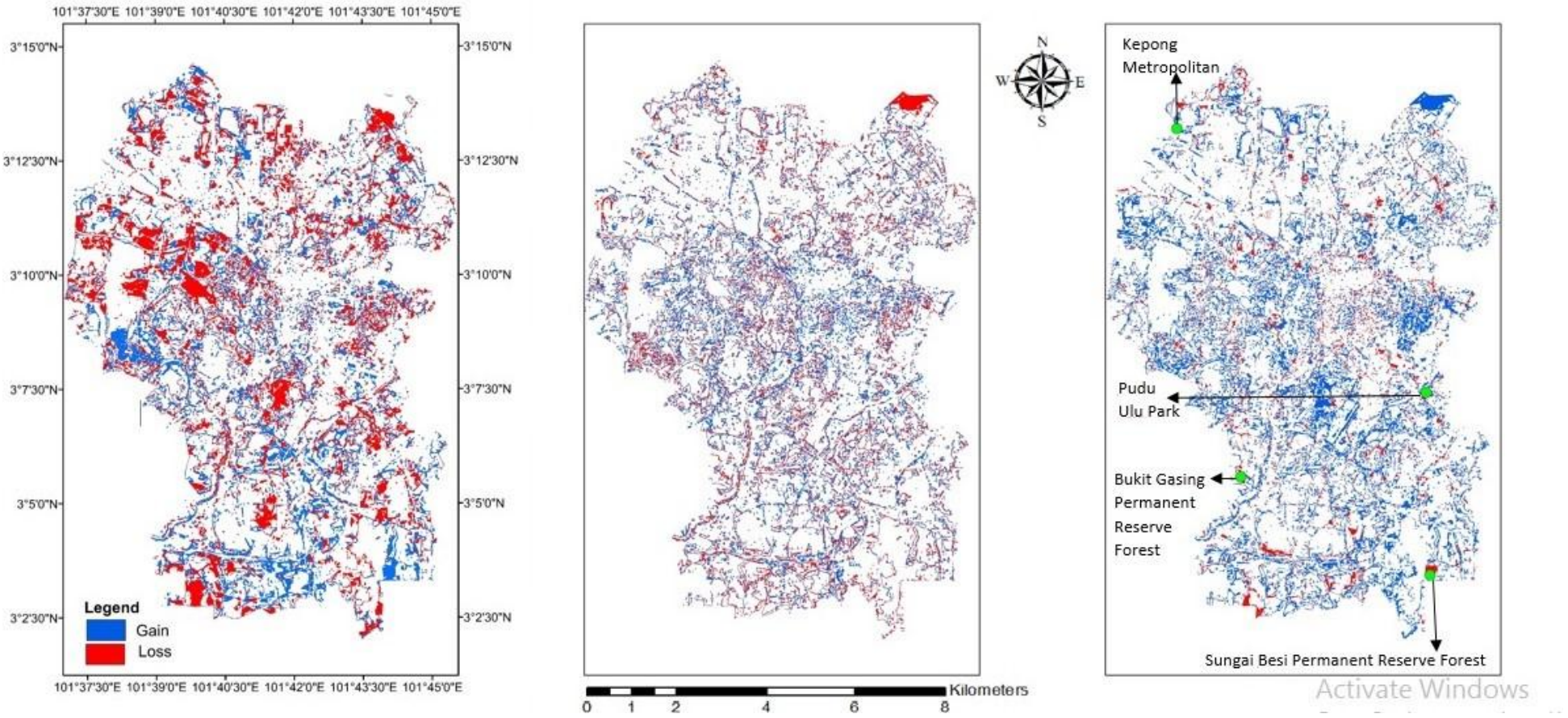


2016

(a)



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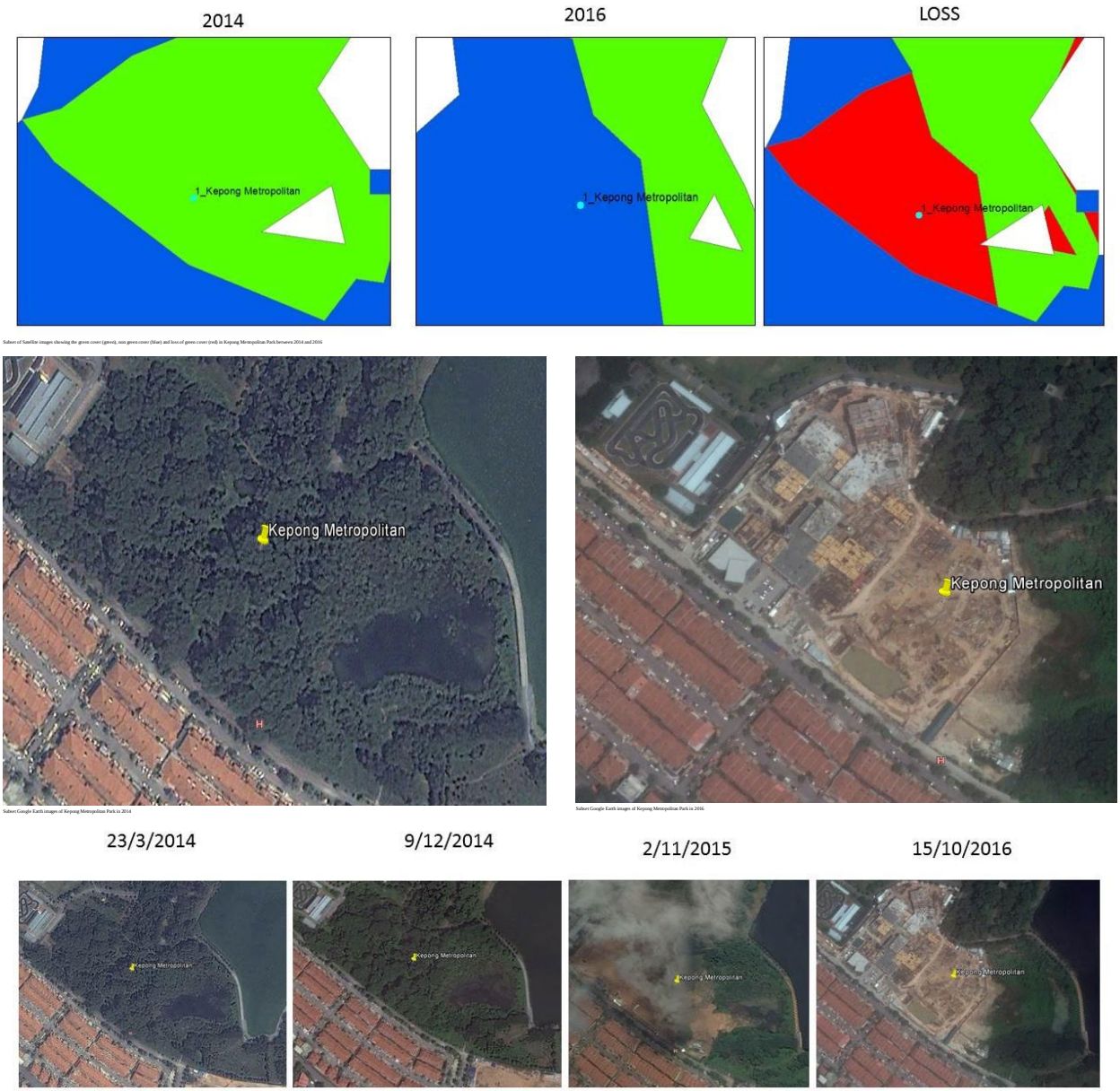
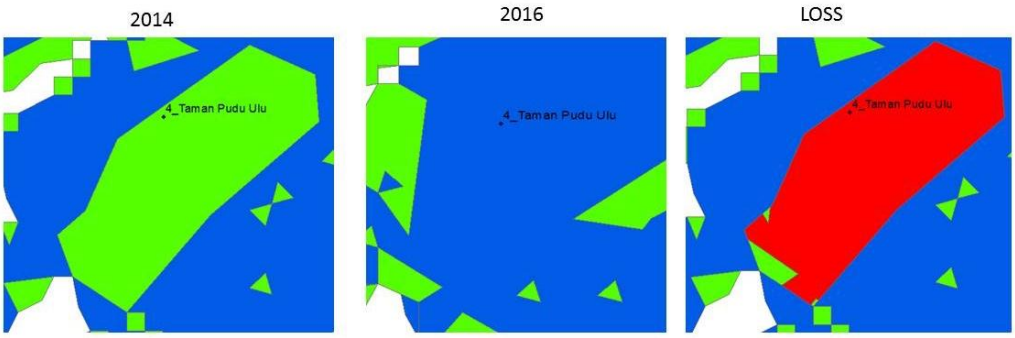
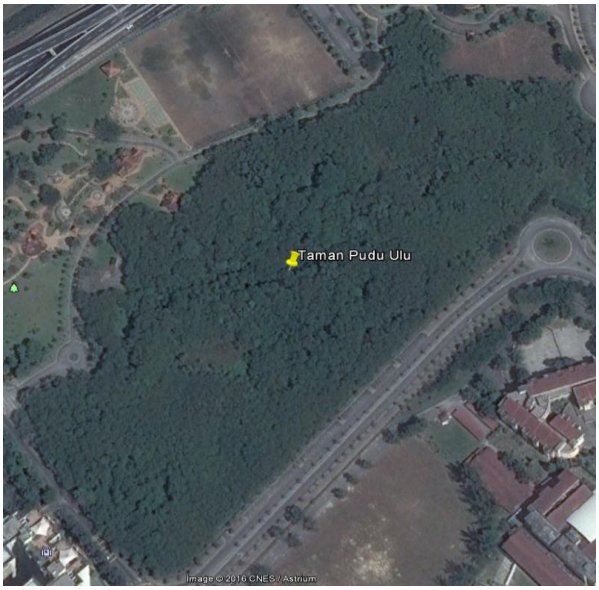


Time series of Google Earth images showing the land use changes in Kepong Metropolitan Park

(a)



Subset of satellite images showing the green cover (green), non green cover (blue) and loss of green cover (red) in Taman Pudu Ulu between 2014 and 2016



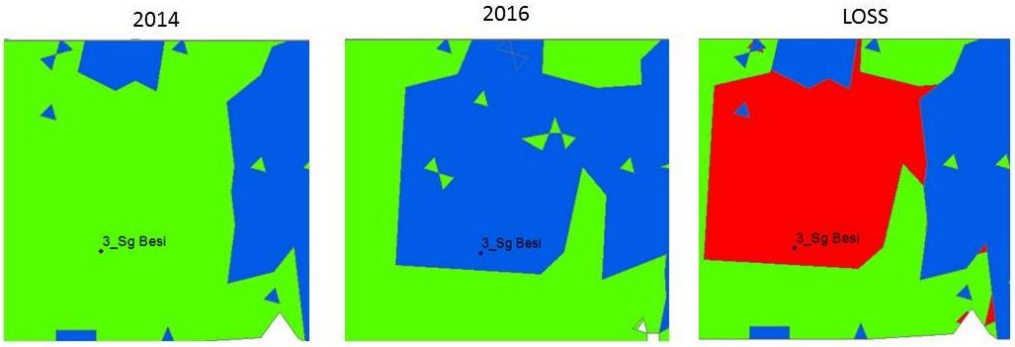
Subset image of Taman Pudu Ulu in 2014

Subset image of Taman Pudu Ulu in 2016

Time series of images showing the land use changes in Taman Pudu Ulu Imagery source: Google Earth

(b)

Figure 7



Subset of images showing green cover (green), non-green cover (blue) and loss of green cover (red) near Sungai Besi Permanent Forest Reserve between 2014 and 2016

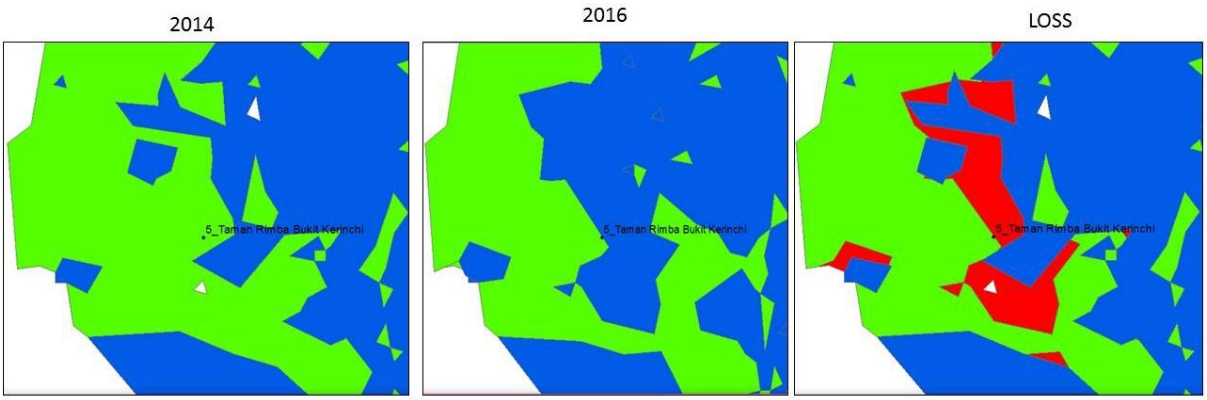
Subset image near Sungai Besi Permanent Forest Reserve in 2014

Subset image near Sungai Besi Permanent Forest Reserve in 2016

Time series of land-use changes at Sungai Besi Permanent Forest Reserve

Imagery source: Google Earth

(a)



Subset of satellite images showing the green cover (green), non-green cover (blue) and loss of green cover (red) near Bukit Gasing Forest Reserve between 2014 and 2016

Subset image near Bukit Gasing Forest Reserve in 2014

Subset image near Bukit Gasing Forest Reserve in 2016

Time-series images of land-use changes at Bukit Gasing Forest Reserve, 2014–2016 Imagery source: Google Earth

(b)

Figure 8

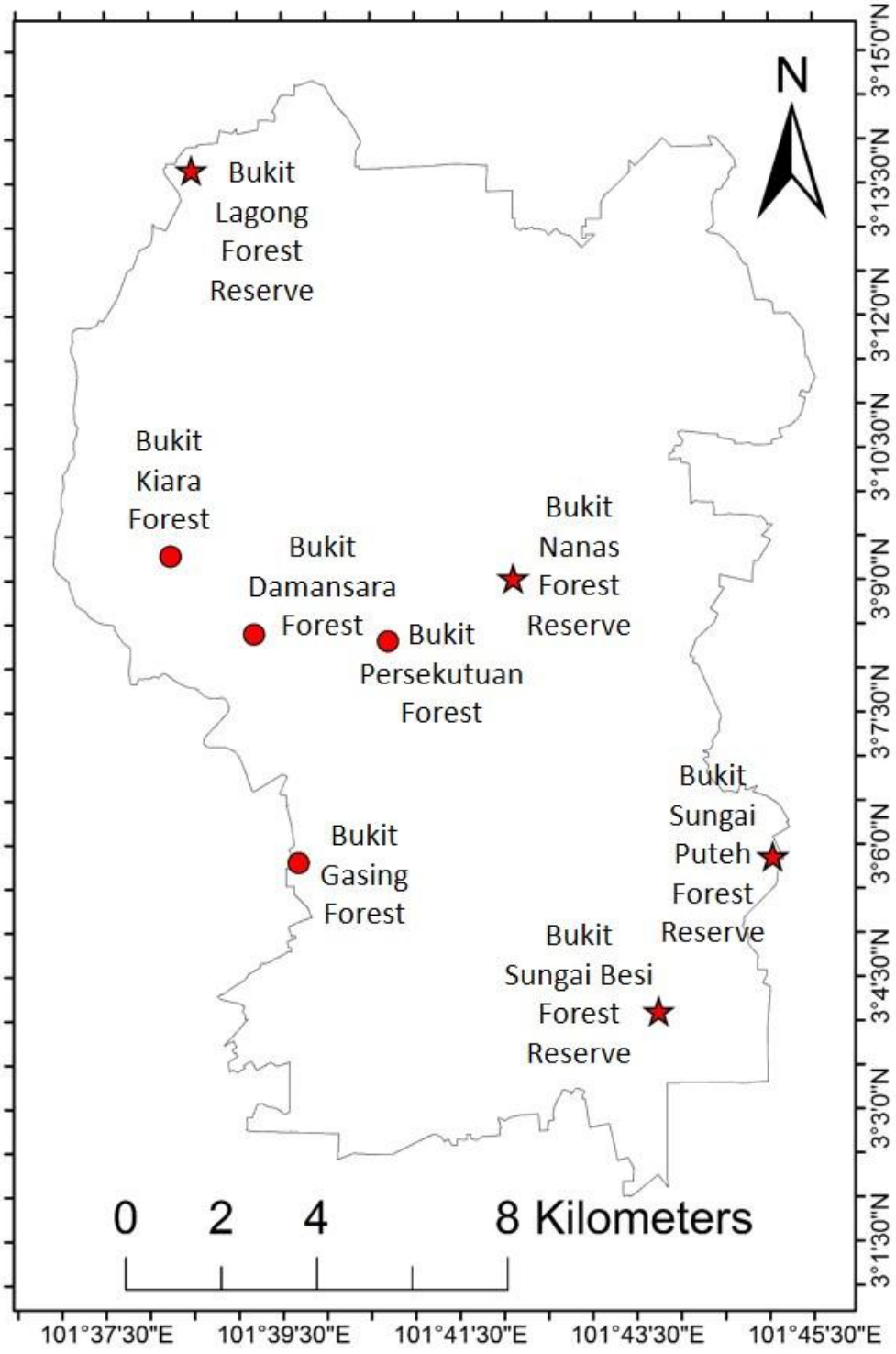


Figure 9

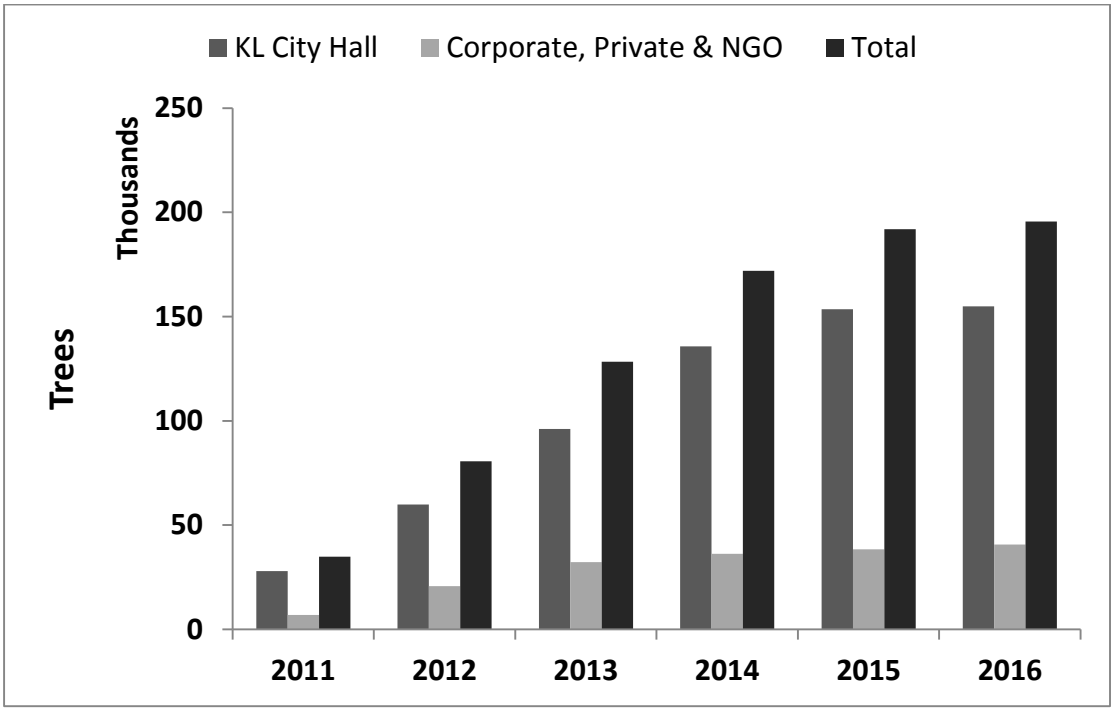


Figure 10

Figure Captions

Figure 1. Trend in population density and provision of open space in Kuala Lumpur (Source of data: PEMANDU, 2014; Hashim, 2010)

Figure 2. Location of Kuala Lumpur, Malaysia and its six strategic zones.

Figure 3. The distribution of Global Positioning System (GPS) coordinates in Kuala Lumpur using Geo XT 3000 handheld GPS that were used to verify ground truth points from Google Earth.

Figure 4. Flow chart showing the overall methods adopted in this study.

Figure 5. Road side trees detected by CLASlite are shown by red arrows (a) and the corresponding Google Earth image showing street trees in Kuala Lumpur city center.

Figure 6. Green cover (a) and its gain and loss (b) in Kuala Lumpur between 2001 and 2016. Note: the no change (white), gain (blue) and loss (red) in the northeast corner of Figure 5b show the effect of cloud cover in 2014 image.

Figure 7. Green cover loss in parks and recreation areas in (a) Kepong Metropolitan Park and (b) Taman Pudu Ulu (Pudu Ulu Recreational Park) in Kuala Lumpur.

Figure 8. Green cover loss in forests (a) near Bukit Sungai Besi Permanent Forest Reserve and (b) Bukit Gasing Forest Reserve in Kuala Lumpur.

Figure 9. Forests in Kuala Lumpur. Reserved forests are marked by stars.

Figure 10. Public-private partnership in tree planting in Kuala Lumpur (source: Kuala Lumpur City Hall)

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Table 1. Interviewees' Affiliations and Positions.

No	Interviewee's Affiliation	Interviewee's Position	Date of interview
1	Physical planning section, Kuala Lumpur City Hall (KLCH)	Urban and rural planner	22 Sep 2016
2	Forestry Department, Federal Territory of KL	Director	13 Oct 2016
3	Universiti Putra Malaysia	Lecturer and former landscape architect, arborist of the Forest Research Institute Malaysia	9 Nov 2016
4	Institute of Landscape Architects Malaysia	Council member and ex-landscape architect & arborist of Putrajaya Corporation	10 Nov 2016
5	Landscape & Recreational Department, KLCH	Deputy Director, Landscape section	11 Nov 2016
6	Landscape Malaysia (non-governmental organization)	Executive Director	6 Dec 2017
7	National Landscape Department	Assistant Director	17 Jan 2017
8	Physical Planning Section, Urban Planning Department, KLCH	Senior Deputy Director	19 Jan 2017
9	PropertyPricetag.com	Chief Executive Officer and former officer of the Performance Management and Delivery Unit Officer of the Malaysia Economic Transformation Program	19 Jan 2017

Table 2: Interview guide to understand the role of gazetted areas in reducing green cover loss and the opportunities and challenges of protecting green cover in Kuala Lumpur.

Main Questions	**Probing Questions**
To what extent do protected area programs prevent green cover loss in KL?	- What type of lands (green spaces) are protected from development? - Can gazetted lands be converted to other land use? - Is there any loss in forest reserves and recreational forests?
What management and governance practices might improve local capacity to monitor and prevent green cover loss to ensure their continued survival and existence in urban areas in Kuala Lumpur?	- Are there any specific guidelines/policies available to monitor green cover? - What is the availability of complete green space/tree inventory data? - Is there any public involvement in monitoring?
What are the challenges and difficulties in protecting the remaining green spaces	- What are financial constraints to manage green spaces? - Is there political interference in protecting green spaces? - Is there any shortage in expertise (i.e. arborists, landscape architects, etc.) to manage green space? - How is the enforcement of laws in protecting green cover in KL?
What are the opportunities to increase more green spaces in KL?	- What are the opportunities for adoption of parks by the private sector? - What are opportunities for the involvement of NGOs, private institutions and property developers in greening KL? - What types/species of trees are to be planted? - What are innovative ways of greening KL (i.e. vertical garden, roof top garden etc.)? - What outreach programs- to communities exist to increase awareness about green cover?

Table 3: Details of the first and second focus group (FGD) discussion participants

FGD	**FGD participants' Affiliation and (Position)**	**No. of participants**
1	Kuala Lumpur city hall (various departments)	9
	Local municipalities (Ampang Jaya, Klang, Subang Jaya, and Selayang) in Klang valley (urban planning department)	4
	Landscape/Architectural firm	1
	National Landscape Department	1
2	Kuala Lumpur City Hall	2
	Company owned by the Malaysia Ministry of Finance, responsible for the development and promotion of the high speed rail (MyHSR Corp)	1
	The Institution of Engineers, Malaysia (IEM)	1
	Free Tree Society KL (NGO)	1
	Malaysia Natural Society (NGO)	1
	WWF (NGO)	1

Table 4: Accuracy assessment of green and tree cover classified using CLASlite algorithm.

	Green		**Non Green**		**Overall Accuracy**		**Tree**		**Non Tree**		**Overall Accuracy**	
Year	PA (%)	UA (%)	PA (%)	UA (%)	Overall	Kappa	PA (%)	UA (%)	PA (%)	UA (%)	Overall	Kappa
2001	93.19	96.80	95.41	90.37	94.08	0.88	96.80	97.15	92.34	91.47	95.60	0.89
2013	85.14	99.57	99.38	79.70	90.40	0.80	96.83	99.53	98.20	88.62	97.11	0.91
2014	97.70	98.58	95.51	92.86	97.18	0.92	97.59	99.42	98.05	92.20	97.70	0.94
2016	98.56	95.14	94.68	98.42	96.67	0.93	99.22	96.69	88.84	97.18	96.80	0.91

PA=Producer Accuracy

UA=User Accuracy

Table 5: Total green and tree cover in Kuala Lumpur from 2001 to 2016.

Year	**Green Cover (Hectare)**	**% Green cover relative to land area**	**Tree Cover (Hectare)**	**% tree cover relative to land area**
2001	6,564	27	4,282	18
2013	5,891	24	3,738	15
2014	6,215	26	3,452	14
2016	7,310	30	4,074	17

Table 6. Green cover loss in Kuala Lumpur city center.

Area	**Total Loss (Ha)**
Near Cochrane Road	3.62
Between Imbi and Pudu Roads	4
China Town	2.3
Near Hotel Renaissance Ampang Road	2