Urban Forestry & Urban Greening 27 (2017) 287–304

Contents lists available at ScienceDirect

Urban Forestry & Urban Greening

journal homepage: www.elsevier.com/locate/ufug

Original article

Quantifying green cover change for sustainable urban planning: A case of Kuala Lumpur, Malaysia

Kasturi Devi Kanniah[a,b,c,*]

[a] MIT-UTM Malaysia Sustainable City Program, Department of Urban Studies + Planning, Massachusetts Institute of Technology, 77 Massachusetts Avenue, Building 9-436, Cambridge, MA, 02139-4307, United States

[b] Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

[c] Centre for Environmental Sustainability and Water Security (IPASA), Research Institute for Sustainable Environment (RISE), Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia

ARTICLE INFO

Keywords:
Urban forest
Tree cover
Remote sensing
CLASlite
Public-private partnership
Gazette

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 6564 ha in 2001–5,891 ha in 2013. However, it increased by 4% in the second, from 6215 ha in 2014–7,310 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 organizations 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.

1. Introduction

Consistent with global trends, 75% of the Malaysian population is expected to live in urban areas by 2020 (United Nations, 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., 2014; 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 al., 2016; Jaganmohan et al., 2016), but even small parks

* Correspondence to: Faculty of Geoinformation and Real Estate, Universiti Teknologi Malaysia, 81310 UTM Johor Bahru, Johor, Malaysia.
E-mail address: kasturi@utm.my.

http://dx.doi.org/10.1016/j.ufug.2017.08.016
Received 3 June 2017; Received in revised form 27 August 2017; Accepted 27 August 2017
Available online 04 September 2017
1618-8667/

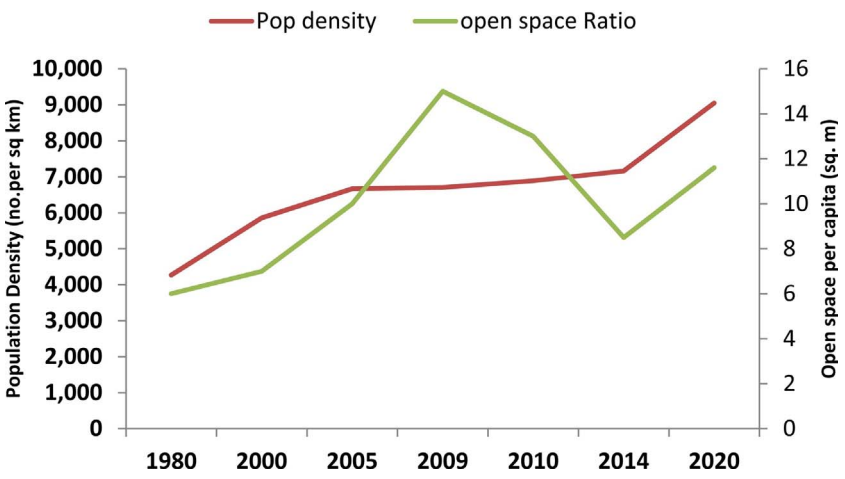

Fig. 1. Trend in population density and provision of open space in Kuala Lumpur (Source of data: PEMANDU, 2014; Hashim, 2010).

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 2000–2.2 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 (Fig. 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 Fig. 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.

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; Curran et al., 2004).

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 and Greenfield, 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 Ho (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?

[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.