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Impacts of population density and wealth on the quantity and structure of urban green space in tropical Southeast Asia

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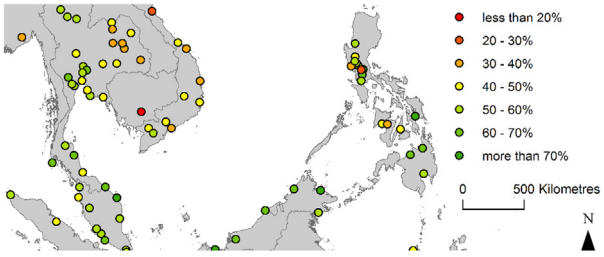
HIGHLIGHTS

- Urban green spaces were mapped for 111 Southeast Asian cities.
- Richer cities had more green space.
- Higher population density cities had less green space and green space per capita.
- Urban population densities and wealth are expected to increase in the future.

GRAPHICAL ABSTRACT



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ABSTRACT

Urban green spaces provide ecosystem services, including climate regulation, food, and opportunities for recreation. The quantity and structure of green space in a city may therefore have consequences for human well-being. Cities in Southeast Asia are rapidly changing as they must accommodate larger populations, and their residents are becoming wealthier. Such changes may have impacts on urban green spaces and the ecosystem services that they provide. To assess the potential impacts of future urbanisation in the region, we analysed existing relationships between city size, wealth, and population density, and (1) the percentage cover of green space, (2) the quantity of green space per capita, and (3) the aggregation of green space. We used remote sensing analysis of Landsat 7 data to classify green space in 111 urban areas in Southeast Asia. Cities with higher population densities had less green space and less green space per capita. Cities with higher GDP per capita had higher percentage coverage of green space. Larger cities had lower percentage coverage of green space and less green space per capita. Cities with higher percentage cover of green space had more aggregated green spaces. Authorities in developing cities should consider protecting ecological assets such as remnant forest patches and river corridors, as re-creating habitats at a later stage of development rarely provides comparable levels of ecosystem services.

1. Introduction

The urban population of Southeast Asia is projected to increase by more than 70% over the next 35 years, to surpass 500 million people by 2050 (United Nations, 2014). Economic growth is expected to continue over the same period, as middle-income countries such as Malaysia reach high-income status (International Monetary Fund, 2015), and previously closed economies such as

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Myanmar become more open to foreign investment (Sun, 2012). These demographic and economic changes are likely to impact the quality and quantity of urban green space available in the region. Given that contact with the natural environment is a fundamental component of well-being (Miller, 2005), such changes may thus have consequences for human well-being.

Urban areas (i.e. towns and cities) are economically important components of modern society (Dobbs et al., 2011). Urban areas are heterogeneous habitat mosaics that integrate man-made structures with green spaces such as parks, gardens, and remnant fragments of natural ecosystems (Loram, Tratalos, Warren, & Gaston, 2007). Urban green spaces can support biodiversity (Dallimer et al., 2012; Strohbach, Haase, & Kabisch, 2009) and provide a range of benefits, known as ecosystem services, to people (Bolund & Hunhammar, 1999; Tratalos, Fuller, Warren, Davies, & Gaston, 2007). For example, parks and nature reserves provide opportunities for recreation and exercise (Gobster & Westphal, 2004; Richards & Friess, 2015), which in turn can improve physical (Maas, Verheij, Groenewegen, de Vries, & Spreeuwenberg, 2006) and mental health (Alcock, White, Wheeler, Fleming, & Depledge, 2014). Urban green spaces can also help mitigate urban heat island effects (Onishi, Cao, Ito, Shi, & Imura, 2010), store carbon (Davies, Edmondson, Heinemeyer, Leake, & Gaston, 2011), and provide food for residents (Wills, Chinemana, & Rudolph, 2009).

The provision of urban ecosystem services in a city is affected by the percentage of green coverage, the per capita green coverage, and the degree to which habitats are aggregated or fragmented (Beninde, Veith, & Hochkirch, 2015; Fuller & Gaston, 2009). In general, we may expect cities with a higher percentage coverage of green areas to hold higher species richness (Beninde et al., 2015) and those with more green space per person to better provide ecosystem services, such as giving greater health benefits (de Vries, Verheij, Groenewegen, & Spreeuwenberg, 2003; Maas et al., 2006). Cities that provide more green space to each person may provide more opportunities for recreation, thus enhancing the quality of life of residents (Fuller & Gaston, 2009). The structure of the green space in a city is also important in determining the benefits that are provided to people; for example, cities with more aggregated green spaces provide larger contiguous patches, which have a greater cooling effect than smaller fragments of similar areal coverage (Bowler, Buyung-Ali, Knight, & Pullin, 2010). The percentage coverage of green space in a city, the per capita green coverage, and the degree of green space aggregation, are therefore likely to have considerable impacts on the urban ecosystem services that are provided, and the net benefits gained by people.

To anticipate the impacts of future urbanisation on green spaces and ecosystem service provision, it is important to understand existing relationships between the geographic, economic, and demographic characteristics of cities and the quantity and structure of their green spaces. Previous research on urban ecosystems has focused on cities in North America and Europe (Beninde et al., 2015), which are among the wealthiest (World Bank, 2015) and most highly urbanised continents (United Nations 2014). In contrast, there is a lack of urban green space research in tropical, less urbanised, and less economically developed regions such as Southeast Asia (a global comparison of urban ecosystem service provision included only one Southeast Asian city in a sample of 100 (Dobbs, Nitschke, & Kendal, 2014)). In contrast to relatively homogenous and wealthy Europe and North America, Southeast Asia provides an opportunity to compare green spaces between cities that vary considerably in their demographic and economic characteristics. The percentage of the total national population living in urban areas varies greatly between countries in the region, from less than 30% in Cambodia and Vietnam to more than 70% in Malaysia, Brunei, and Singapore (United Nations 2014). There is also considerable variation between countries in the degree of economic development, allowing comparisons to be made between the high-income economy of Singapore, the middle-income countries, and low-income Cambodia (World Bank, 2015). Similarly, urban areas across Southeast Asia vary in their size and population density, from relatively small, dispersed cities such as Rayong in Thailand to the densely packed megacity of Jakarta in Indonesia. Despite the considerable changes in city sizes, population densities and levels of economic development that are expected to occur in Southeast Asian cities in the near future, it is not clear how these changes will impact the urban green space environment.

The aim of this study was to identify general patterns between the quantity and structure of urban green space in Southeast Asian cities, and the demographic and economic characteristics of those cities. The objectives were to analyse (1) the proportional coverage of green space in urban areas, (2) the per capita quantity of green space in urban areas, and (3) the degree to which green spaces are aggregated or fragmented across the urban landscape. These variables were analysed in relation to indicators of population density, wealth, and city size. We analysed data from 111 urban areas across nine countries in Southeast Asia using land use maps classified from 2012 Landsat satellite imagery.

2. Methods

2.1. Defining city boundaries

Different countries in Southeast Asia use different methods to delineate the boundaries of their urban regions. To systematically define the boundaries of urban areas across Southeast Asia we used night-time satellite images, which are commonly used in urban studies (Sutton, Roberts, Elvidge, & Meij, 1997; Sutton, Roberts, Elvidge, & Baugh, 2001). Specifically, we used satellite images provided by the Visible Infrared Imaging Radiometer Suite (VIIRS) sensor on board the Suomi National Polar-orbiting Partnership (NPP) satellite operated by NASA (Table 1). The satellite was launched on October 2011 and provides pre-processed false colour night time images with a resolution of 750 m by 750 m resolution. These images are freely available (http://earthobservatory.nasa.gov/Features/NightLights/page3.php).

Pixels with the greatest luminosity were assumed to be urban. Hence, we set a threshold of luminosity to delineate urban pixels from non-urban pixels. Pixels were defined as urban if their luminosity value was in the top 2% of the possible range (a value of greater than 250 in Band 1 of the VIIRS image). This threshold was chosen following some manual experimentation, and provides a consistent definition of “urban” over the whole study area. The countries of Southeast Asia have a high level of electrification, especially in large urban areas; in 2011 less than 5% of people living in urban areas lacked electricity (International Energy Agency, 2013). Therefore, we do not expect country-specific differences in elec-

Table 1
Source datasets for the variables used in statistical modelling.

Variable	Source datasets
Percentage of green cover in a city	Night-time satellite imagery and Landsat 7.
Population density	Night-time satellite imagery and McKinsey Global Institute.
GDP per capita	McKinsey Global Institute.
City land area	Night-time satellite imagery and Landsat 7.
Per capita green space provision	Night-time satellite imagery and McKinsey Global Institute.
Aggregation index	Landsat 7.