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Remote sensing based analysis of urban heat islands with vegetation cover in Colombo city, Sri Lanka using Landsat-7 ETM+ data

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ABSTRACT

Urbanisation leads to rapid constructions, which use low albedo materials leading to high heat absorption in urban centres. In addition, removal of vegetation cover and emissions of waste heat from various sources contribute to the accumulation of heat energy, leading to formation of urban heat islands (UHIs). UHIs have many adverse socio-environmental impacts. Therefore, spatial identification of UHIs is a necessity to take appropriate remedial measures to minimise their adverse impacts. Satellite remote sensing provides a cost-effective and time-saving methodology for spatio-temporal analyses of land surface temperature (LST) distribution.

In this study, thermal bands (10.40–12.50 μm) of Landsat-7 ETM+ imagery acquired in 3 distinct dates covering Colombo city of Sri Lanka were analysed for the spatio-temporal identification of UHIs. Vegetation cover of Colombo city was extracted by using NDVI method and subsequently examined with the distribution of LST.

A deductive index was defined to identify the environmentally critical areas in Colombo city based on the distribution of LST and availability of vegetation cover. Accordingly, Colombo harbour and surrounding areas were identified as the most critical areas. Remedial measures can be taken in future urban planning endeavours based on the results of this study.

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1. Introduction

Widespread industrialisation and migration of rural population to urban areas lead to urban population growth, while expanding the urban sprawls. As of year 2010, 50.5% of the world's population resided in urban areas implies that majority of the world population lives in urban areas instead of rural areas. In the year 2050, urban population residing in urban sprawls of developing countries is expected to double in number (United Nations, 2011). To accommodate urban population growth, urban infrastructure such as roads, bridges and residential buildings, need to be developed leading to rapid changes in land use patterns.

Vigorous urbanisation has its beneficial and adverse consequences affecting environmental and social aspects of inhabitants. Highly effective supply chains of basic facilities, easy access to quality education, medical and social services, leisure activities, concentration of resources, better economical and job opportunities, etc. can be considered as beneficial aspects of urbanisation. Though urbanisation has significant benefits as previously stated, there are a number of adverse socio-environmental effects as well.

One of the major reasons for these adverse environmental impacts is removal and replacement of vegetation cover by various built-up structures which cause environmental pollution, climate change and breakdown of ecological cycles. Most of these adverse environmental effects can be minimised by identification of problems and implementation of proper urban planning systems with sustainable solutions.

The roof tops and walls of high rise structures with darker surfaces, parking lots, roads and pavements constructed with asphalt and concrete tend to have low albedos. These dark low-albedo surfaces absorb higher amount of solar radiation and convert it to thermal energy. Consequently, excess amounts of heat energy accumulate in the immediate vicinity to above average levels. This phenomenon causes urban areas to have elevated temperatures compared to the surrounding rural areas. This temperature difference forms the land effect called urban heat islands (UHIs) (Comarazamy et al., 2010). These areas tend to have an above average temperature all year around and the temperature difference can be as high as 12 °C. Generally, the temperature difference is highly pronounced at night time than the day time and is noticeable when the winds are weak (Oke, 1987). Removal of vegetation cover is another major contributor to the UHI formation. While lowering land surface temperature (LST) by providing shade; trees and vegetation decrease the ambient air temperature through evapotranspiration process where they release water vapour to the surrounding atmosphere. Conversely, built-up areas consist of elevated temperatures as the vegetation is replaced by the artificial impervious surfaces such as roads, buildings, pavements, parking lots, etc. (Cheng et al., 2010; Gonzalez et al., 2005; Lo et al., 1997; US Environmental Protection Agency, 2008). Properties of the materials utilised in construction of urban structures, such as solar reflectance, heat capacity and thermal emissivity plays a major role in formation of UHIs. In addition, the waste heat generated by factories, air conditioners and motor vehicles which are ubiquitous in urban areas contribute to the formation of UHIs (Guhathakurta and Gober, 2007; Khan and Simpson, 2001; Sailor and Lu, 2004; Weng, 2010).

Though, the disparity of temperature is not large, it can cause several noteworthy socio-environmental problems in urban areas. UHIs adversely affect the air quality in the region due to the production of pollutant gases such as ozone. Chemical reactions between volatile organic compounds and various oxides of nitrogen (i.e. NO and NO_2) prevalent in warm weather and sunlight produce this toxic ozone gas (Cardelino and Chameide, 1990; US Environmental Protection Agency, 2012). Further, it affects the water quality by increasing the temperature of the water bodies through heated storm water runoff draining into the water bodies in the area, consequently stressing aquatic ecosystems (US Environmental Protection Agency, 2012). In addition to the anomalies in temperature, heat waves generated by the UHI effect can change the climatic patterns including rainfall and wind characteristics of urban areas (Baik et al., 2000; Tan et al., 2010). UHIs indirectly increase the consumption of energy of buildings by raising the requirement for air-conditioning in urban areas. As a result, power plants emit more pollutant gases in the process of generating the required extra electricity (Akbari et al., 2001; Devanathan and Devanathan, 2011) and this effect continues as a positive feedback loop degrading the environmental quality even further.