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Modeling a Tropical Urban Context with Green Walls and Green Roofs as an Urban Heat Island Adaptation Strategy.

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Abstract

Urban green infrastructure (UGI) has gained increasing attention as urban heat island (UHI) mitigation and resilience strategy recently. This preliminary study investigates the outdoor temperature behavior with different fractions of selected UGIs, in tropical Colombo, the commercial capital Sri Lanka with a computer based simulation for a hot, humid end–summer sunny climate conditions in August. Seven UGI scenarios were defined under real scale modeling by ENVI–met, as T1 (existing UHI), green roofs T2,T3,T4 and green walls T5,T6,T7 by considering vegetation percentage and existing geometry. Outdoor temperatures were measured in three different locations using receptors (R1, R2 and R3) by considering the positioning with building walls and asphalt roads in the sensible height of 1.5m. Software was validated with 0.9657 R^2 for simulated versus real ground measurements for T1 in same location initially. Results have enlightened that different green infrastructures significantly reduced the temperature with the vegetative fraction and highest reduction of outdoor air temperature was recorded at 1500h in a typical day. R1 and R3 had given the best reductions of temperature by 2.03^{0}C and 1.88^{0}C, respectively at green wall for 100% in East–West direction while R2 temperature reduction was 1.64^{0}C for green roof 100% compared to existing UHI scenario (T1).

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Keywords: ENVI-met; green roofs; green walls; thermal comfort; urban heat island

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1. Introduction

Exponential population growth demands, higher rates of urbanization and industrialization for comforting lives with complex necessities. 50% from the world population (3.4 Billion) is settled in urban areas and it is predicted that the intensive growth and inhabitation in cities will reach 66% (5.0 Billion) by 2030 [1, 2]. This booming population needs more spaces to live and work, hence, urban areas are rapidly developing with buildings and dwellings by replacing existing vegetation and creating even mega cities such as Tokyo, Shanghai, Jakarta, Karachi and Seoul [2]. A typical urban environment features with a little vegetation amongst high rise buildings and transport infrastructures that categorized as anthropogenic surfaces [3]. Such an excessive, unplanned growth and man-made alterations can bring undesirable impacts on local climatic features such as urban heat island (UHI), a regional effect of global warming and climate changing. It has gained a significant attention as a severe regional issue due to its present development into disastrous levels around the world. Larger cities with one million people have experienced an increased average temperature of 1–12^{0}C compared to surround rural and suburbs, while smaller cities do not express a noticeable heat change [4].

Causes of UHI are not identical in different climates or city contexts, but low surface albedo, building geometry and less greenery were identified as key factors [5, 6]. Generally, anthropogenic surfaces (non–reflective, non–natural heat absorbing and water–resistant impervious, that can absorb higher fraction of incoming solar radiation) which were replaced the naturally vegetated surfaces are generating huge amount of heat from solar radiation that consumed and re–radiated by urban structures [6, 7]. Canyon radiative geometry, thermal properties of materials, anthropogenic heat released from combustion of fuels for vehicles, thermal power plants, animal metabolism and urban greenhouse are the further reasons that manipulate the UHI [8]. Factors such as wind speeds, cloud cover, season, city extent and population size, and time of the day influence on UHI intensities [9].

UHI significantly influences on decreasing outdoor and indoor air quality, thermal comfort and healthiness of city dwellers and occupants and increasing the buildings' energy consumption [10–16]. Deterioration of thermal comfort of living environment is the basic impact of UHI and cities like Paris, Pune and Hong Kong were experienced an excessive heat growth of 14^{0}C, 10^{0}C and 4^{0}C, respectively [17]. Several disasters, which occurred recently due to the excessive heat and urban related heat waves in the world have been made a significant attention on UHI impacts. More than 70,000 excess deaths were recorded due to the heat wave of summer 2003 in Europe [18] while 400 deaths were recorded in Karachi-Pakistan in 2015 [19]. Hence, implementing of necessary mitigation scenarios is needed in city designing and planning. Urban green infrastructure (UGI) has been increasingly promoted as a strategic measure to mitigate heat stress in built environments.

Colombo, the commercial capital of Sri Lanka has a continuous developing building geometry and considered as a warm and humid, tropical city. It has been suffering from UHI intensities of 0.09^{0}C–4.4^{0}C compared to surround rural and suburb areas. Moreover, Colombo is highly humid area and with this higher temperature values, it creates undesirable living condition and poor thermal comfort. According to the 'local climatic zones classification' (LCZ) [20], Colombo remains 'low rise' for large area, however the mixture of 'midrise' and 'high rise' blocks [21, 22] act as an incentive for UHI.

Currently in Sri Lankan context, climate change adaptation and building resilience have not much been undertaken since it is a novel research field. This paper presents a preliminary study to investigate the future mitigation and resilience strategies for climatic change impacts resulted due to UHI by considering outdoor temperature behavior in tropical urban context with various combinations of specified UGIs. ENVI–met V4, a world recognized simulating and modeling software for architecture, engineering and city planning has been used for this simulation work. Hence this research study would be fulfilling gaps in tropical climatic context by not altering the existing urban geometry and thermal characteristics of materials but, manipulating the urban vegetation of the area.

2. Methodology

Methodology of the study involved real–scale modeling of selected urban context by using ENVI–met V4 [23].

a) Study area selection