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URBAN GREEN SPACE PLANNING: A MITIGATION STRATEGY FOR URBAN HEAT ISLAND EFFECT

A Case Study of Hanoi, Vietnam and Columbo, Sri Lanka

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Abstract: Urbanization has resulted in many critical issues like increase in pollution levels, sudden climatic changes and the rise of temperature in the urban areas, i.e., the formation of Urban Heat Islands. Urban green spaces, an important component of urban ecosystems, provide many environmental and social services that contribute to the quality of life in cities. One of the key tasks of planners is how to optimize the benefits of urban green spaces. The paper aims to study the urban heat island (UHI) effect and its mitigation strategies of the city of Hanoi, Vietnam and Columbo, Sri Lanka under the present land use conditions. The consequences of unplanned urban expansion are reviewed and supported by the identification of the contributing elements, including UHIs, increased carbon emissions, and air pollution. The research is used to develop planning recommendations that are meant to help reduce the Urban Heat Island Effect.

Keywords - Urbanisation, Urban Heat Island, Urban Green Space, Temporal variations, Landuse Landcover

I. INTRODUCTION

Urbanization is a crucial process that is required for human growth, and it has been happening considerably more rapidly in developing nations than in the developed ones. It has resulted in many critical issues like increase in pollution levels, sudden climatic changes and the rise of temperature in the urban areas, i.e., the formation of Urban Heat Islands. The landscape is altered when areas/regions develop. Open space and vegetation get replaced by structures, roads, and other infrastructure, as a result of which, permeable and moist surfaces turn into impermeable and dry surfaces.

In contrast to their rural surroundings, urban centres have grown significantly throughout time, especially in areas with densely packed structures and minimal vegetation, where temperatures tend to be higher. Urban heat islands (UHI) are the term given to this trend. Because airborne pollutants collect and radiate heat into urban canyons, pollution also plays a role in this situation of increasing Urban Heat Island.

British engineer Guy Stewart Callendar (1898-1964), was the first scientist to suggest that temperature data showed a worldwide warming trend and also, that the trend might be driven by the greenhouse effect that humans have created.

The phenomenon of Urban Heat Island was first was analysed and researched by Luke Howard in 1810’s, and is the most investigated climate effects in cities around the world. He postulated in 1833 that the excessive heat in cities during the summer was brought on by the city's vertical surfaces absorbing more solar radiation and the dearth of accessible humidity for evaporation. Surprisingly, Howard's theories proved correct in the terms of Urban Heat Island.

This paper aims to determine the impact of green spaces on urban heat island, to come up as a mitigation strategy for the same. The objective is to analyse the relationship between Urban Heat Island and different Landuse characteristics. The study will be a review of previous research papers and study of tools and techniques used by researchers to accomplish the goal of analyse green space planning to mitigate the urban heat island effect in an urban area.

2. LITERATURE REVIEW

2.1 Factors Contributing To UHI

The principal causes of UHI formation are described as follows:

1.1.1 Urban sprawl and loss of green cover

Urbanisation at an unprecedented rate is leading to increased, dense built-up areas and more impervious surfaces such as roofs, asphalt roads, paved sidewalks with reduced green and soft spaces, resulting in less water infiltration. Masonry structures of urban centres absorb solar radiation more efficiently as compared to that of vegetation covers. Urban sprawl results in many adverse impacts that have direct effects on quality of life. It impedes evapotranspiration, shade and removal of carbon dioxide, all the processes that help to cool the surrounding air.

It is generally characterised by:

i. Low-density dispersed settlement situated in large lots.
ii. High dependence on automobile vehicles.
iii. Increased impervious surface area.
iv. Habitat defragmentation and degradation.

1.1.2 Thermal Emissivity of building materials and Albedo

The thermal behaviour of pavements and other ground surfaces, as well as the effects that this thermal behaviour has on people and the environment, are significantly influenced by albedo (or solar reflectance). Materials absorb considerable heat during the day, which they release back into the atmosphere at night, thus contributing to the urban heat island effect in an urban area. Building here becomes urban heat canyons.

In light of the fact that the differences in the albedo of any surface between urban and rural areas is a significant factor in the resulting temperature differences between the two, improving the albedo of surfaces in urban areas would therefore help minimize the Urban Heat Island Effect.

1.1.3 Urban Morphology

Urban heat islands are greatly influenced by the three-dimensional geometry, orientation, and spacing of a city's structure. Urban canyons are formed when airflow is restricted due to dense high-rise construction and small winding streets, which traps heat from the sun's radiation and human activity. Tall structures and the frequently accompanying narrow streets obstruct airflow, slow down the wind, and hence lessen any cooling effects that otherwise could occur naturally. This is called the Urban Canyon Effect.

Many buildings found in urban areas have dark surfaces, thereby decreasing albedo resulting in increased absorption of heat causing increased UHI effect.

1.1.4 Heat Generated by Human Activities

Heat generated by vehicles, industrial activities, etc. contributes to the development of heat islands. Anthropogenic heat varies by urban activity and infrastructure, with more energy intensive buildings and transportation producing more heat.

Due to need for mass transportation system human activities such as the use of air-conditioning devices, factories and transportation can also aggravate this effect. Also, the urban regions become warmer due to efficient transportation systems and the unrestricted usage of fossil fuels.

A manifold increase in construction activities, as cities grow, carbon-absorbing materials like asphalt and concrete are required to build everything from small urban dwellings to complex infrastructure. The mean surface temperatures of urban centres rise as a result of the enormous amounts of heat they trap.

So, we can say that Urban Heat Islands:

i. Decreases air quality by increasing the production of pollutants, and
ii. Decreases water quality as warmer waters flow into area streams and put stress on their ecosystems.

1.2 Types of Urban Heat Islands

There are two types of UHIs based on their formation. Different techniques are used to identify them and measure them and their impacts and to some degree, the methods to mitigate.

1.2.1 Surface Urban Heat Island (SUHI)

The SUHIs are formed due to the heat storage of impermeable materials and anthropogenic heat brought by the urbanisation development. Urban surfaces like roads and rooftops absorb and release heat more than other natural surfaces, which results in the formation of these heat islands. During the daytime when the sun comes up, surface heat islands frequently reach their peak intensity. This urban heat island is detected remotely. Thermal infrared data that can be used to derive land surface temperatures is used to observe it. Near-surface air temperatures and land surface temperatures typically have strong ties. As a result, a valid predictor of the atmospheric urban heat island, is the surface urban heat island.

1.2.1.1 Atmospheric Urban Heat Island

Urban heat islands are regions with warmer air in comparison to adjoining rural areas having cooler air. These heat islands are divided by experts into two categories:

1.2.1.2 Canopy layer heat islands

These urban heat islands exist in the layer of air where people live, from the ground to below the tops of trees and roofs.

1.2.1.3 Boundary layer heat islands

These urban heat islands originate at the level of rooftops and treetops and continue upward until urban landscapes have no further effect on the climate. This area normally doesn't extend more than 1.5 km (one mile) below the surface.

1.3 Relation between Surface and Atmospheric Heat Islands

In particular in the canopy layer, which is closest to the surface, surface temperatures have a large but indirect impact on air temperatures. For instance, parks and other vegetated places, which frequently have cooler surface temperatures, help to cool the air.

On the other hand, densely populated places often result in an additional air temperature. The link between surface and air temperatures, however, is not consistent due to air mixing inside the atmosphere, and air temperatures often vary less than surface temperatures throughout an area.

1.4 Research- I: Colombo, Sri Lanka

1.4.1 Introduction

(Dikman Maheng, 2019)This paper uses UrbClim, a boundary climate model that runs two kinds of simulations, namely urbanisation impact simulations and greening simulations, to investigate the existence of UHIs and the impact of green areas to mitigate the impacts of UHIs in Colombo, Sri Lanka. This paper illustrates the sensitivity of urban heat island to vegetation cover in both rural and urban locations. Two groups of green area conditions that represent decreasing and increasing green areas are simulated, and the results are compared with the reference year. The objective of this study is to show how increased green area can reduce UHI intensity, by demonstrating the sensitivity of UHI to vegetation cover in both urban and suburban areas. The study starts with a hypothesis that changes in the quantity and distribution of green space have significant impacts on the spatial and temporal temperature distribution in urban areas.

1.4.2 Relationship of UHI and UGS

(a). **Composition:** (Dikman Maheng, 2019) Refers to vegetation density and variety of land-cover types, green space size, as well as spatial distribution. Composition of UGS can be more significant to cooling effects as in in Hanoi, Vietnam, the transformation of agricultural land into the impervious (built-up) surface due to urbanization and industrialization between 2003 and 2015 has increased the mean land-surface temperature (MLST).

Results: Changing the levels of green space influence air temperature changes and generate various temperature patterns.

(b). **Configuration:** (Dikman Maheng, 2019)The configuration of UGS is related to spatial pattern as well as the layout of UGS including aggregation, shape, and cohesion of patches. In a particular configuration, UHI intensity can be significantly increased or decreased by different spatial arrangements of ugs. The configuration or spatial distribution of urban green space can influence the flow of energy or the energy exchange among different land-cover features.

Results: There is no significant relationship between the degree of aggregation of green space and mean temperature, still it has been found that in a particular space, dispersed configuration or evenly distributed UGS has led to a decrease of the mean temperature.

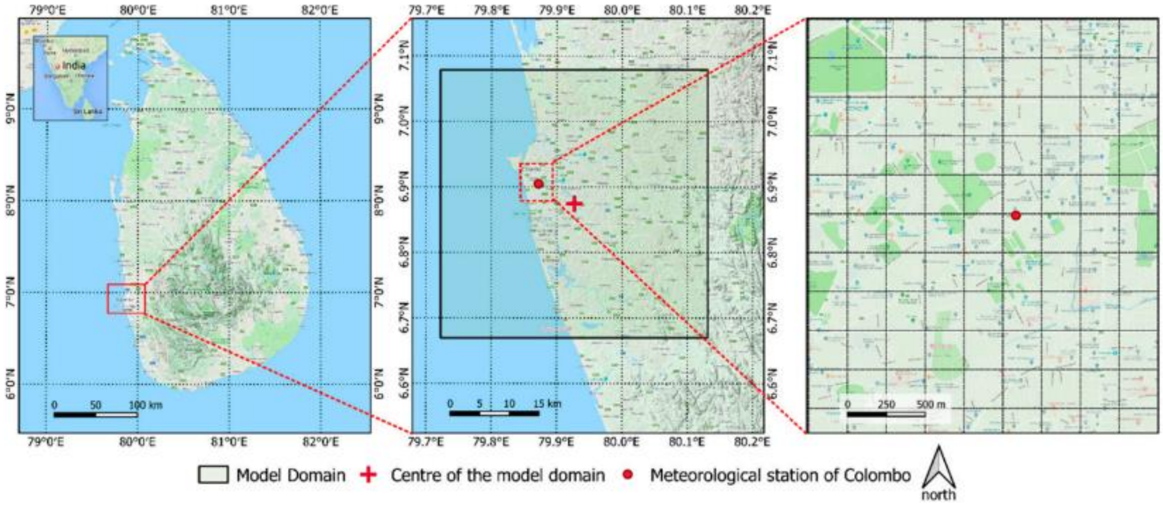

Figure 1: Figure showing location of study area

1.4.3 UrbClim Model Setup and Validation

(Dikman Maheng, 2019)An urban boundary climate model called UrbClim was created by combining a 3-D atmospheric boundary layer module with a land-surface scheme that contains simplified urban physics. The model's high spatial resolution, up to 100 m, is intended to replicate the temperature and heat-stress fields. The surface module and the atmosphere module are the two main modules that make up UrbClim.

The urban terrain is represented in the UrbClim land-surface scheme by an impermeable slab with the appropriate values of emissivity, albedo, and aerodynamic and thermal roughness length.

The UrbClim performance has been validated by simulating UHI in Toulouse (France), Ghent (Belgium), Antwerp (Belgium), and Bilbao (Spain). Two Landuse maps were generated for the years 1997 and 2015, which were based on the UrbClim land-use classes.

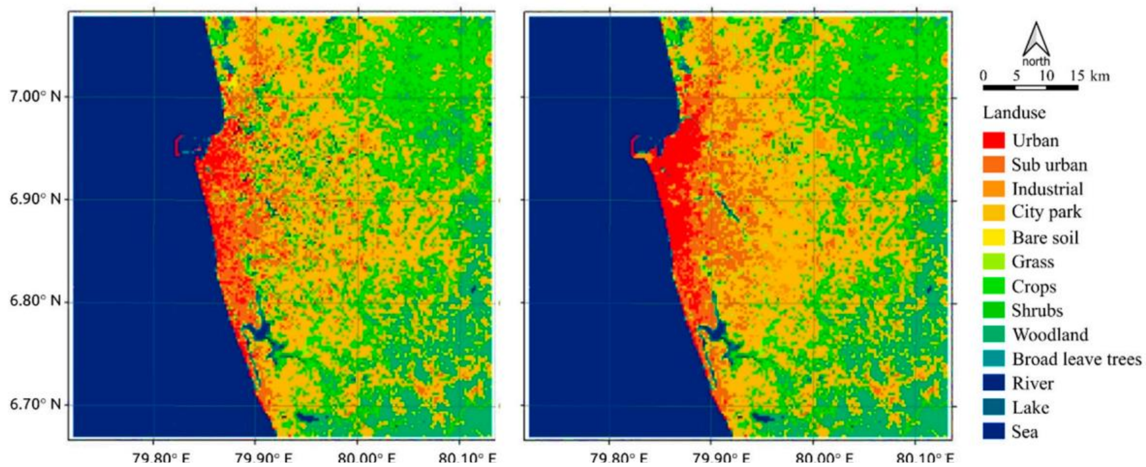

Figure 2: Landcover Map (a). 1997; and (b). 2015

(Dikman Maheng, 2019) To investigate the sensitivity of the UHI to green area in the city of Colombo, this study was conducted by using two groups of numerical simulations, namely "urbanization impact simulations" and "greening simulations". The first urbanization impact simulation was performed to identify the existence of the UHI due to land-use change from 1997 to 2015, while the second simulation was intended to investigate the extension of the UHI by expanding urbanization to suburban areas. The greening simulations were started by increasing green cover in urban areas by 10%, and comparing the result with the existing condition in 2015. The similar procedure was applied when green areas increased by 20% and 30%.

1.4.3 Results & Conclusion

(Dikman Maheng, 2019) Increasing green areas also influenced the spatial distribution and contribution of urban temperature. The difference in temperature between urban and suburban areas, which helps to prevent UHI formation, may be influenced by the temperature drop in urban areas. The effect of green space on the geographical and temporal distribution of urban temperature as well as UHIs has been investigated in the current study. Therefore, it is important to establish the connection between urban planning, green space, and UHIs and to determine how sensitive the UHI effect is to the availability of green space.

1.5 Research- II: Hanoi, Vietnam

The study focuses on developing green spaces in urban areas to improve micro-climate, by introducing a program for developing green spaces in urban areas through:

i. Land suitability analysis based on GIS
ii. Quantifying green areas based on the ecological factor threshold method to maintain ecological balance
iii. Applying landscape-ecology principles in organizing green spaces in urban areas.

1.5.1 Methodology

i. Identifying suitable sites for conserving and developing green spaces is the first important step to ensure their roles and functions.
ii. Site information can be gained by using land suitability analysis (LSA) based on GIS.
iii. Applying the ecological factor threshold method will help quantify how much green area is necessary to maintain an ecological balance in urban areas.

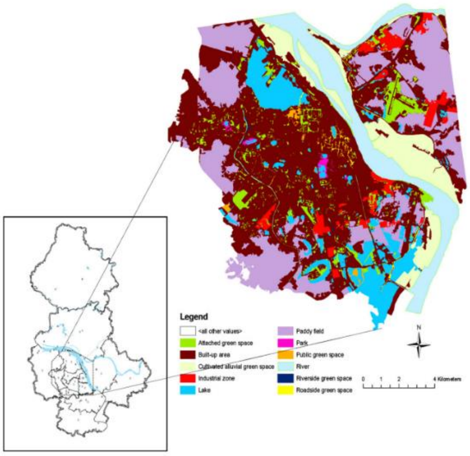

Figure 4: The steps involved in the development of green spaces

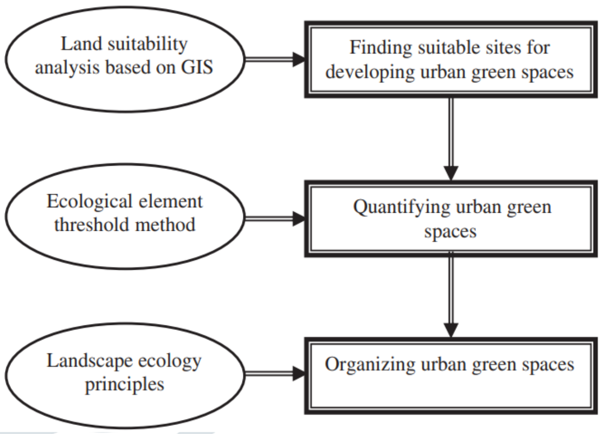

Figure 3: The study area of Hanoi, Vietnam

(Pham Duc Uy, 2008) Hanoi – the capital of the Socialist Republic of Vietnam, is the political–economic–cultural–scientific and technological center of the whole country with a latitude from 201530 to 211230 north, and longitude from 1051440 to 1061020 east. Hanoi is an ancient city with nine urban districts and five rural districts.
(Pham Duc Uy, 2008) The LSA was supported by the spatial analysis functions of GIS through steps including: identification and collection of spatial data, weighting with the analytic hierarchy process (AHP), data integration and GIS analysis, and output evaluation.
One of the most crucial processes in suitability analysis is weighting, which has a precise impact on the results and is made challenging by the interactions between many components.
(Pham Duc Uy, 2008) At present, Hanoi city resembles a hybrid of the basic forms (linear, centralized and gridiron), which express physical and cultural influences through time. According to the 2020 Hanoi Master Plan, the city will be planned and developed following a centralized form where the city center is marked by the ancient quarter.

1.5.2 CONSCLUSION

The results of this analysis gave some implications for the 2020 urban Green Space planning in Hanoi, Vietnam, and the city will allocate the per capita $18m^2$ for green spaces. Moreover, the city will focus on development of diverse green space planning to create a green network ecology for the city more effective than the sum of the individual green spaces.

2. SUMMARY

The importance of urban green-spaces were known for decades; however, the relationship between urban liveability and green-spaces as incorporated in overall urban green structures has become the focus from past few years. A planning model based on diversified and refined land-use supply can better integrate the ecological performance and other functions of UGS. The research results can provide methodological references for planning different types of UGS and innovative insights for smart UGS planning and sustainable landscape design.

3. RECOMMENDATIONS

Based on the studies of different cities worldwide, some recommendations are as follows:

i. The green spaces to be proposed shall not be concentrated, instead should be appropriately scattered as per the demand of the urban area and its rising temperature.
ii. Multiple regression analysis shall be done before spatializing the UHI of any urban area, thereby providing green spaces.
iii. Awareness programs should be conducted inorder to conserve the remaining green spaces within cities, so as to lessen the effect of UHI. Community level involvement shall be done inorder to make people know the relevance of UGS against UHI.

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5. REFERENCES

1. Unger, J.; Bottyán, Z.; Gulyás, A.; Kevei-Bárány, I. Urban temperature excess as a function of urban parameters in szeged, part 2: Statistical model equations. Acta Climatol. Chorol. 2001, 34–35, 15–21.
2. Charabi, Y.; Bakhit, A. Assessment of the canopy urban heat island of a coastal arid tropical city: The case of Muscat, Oman. Atmos. Res. 2011, 101, 215–227.
3. Miao, S.; Chen, F.; LeMone, M.A.; Tewari, M.; Li, Q.; Wang, Y. An observational and modeling study of characteristics of urban heat island and boundary layer structures in Beijing. J. Appl. Meteorol. Climatol. 2009, 48, 484–501.
4. Towns & Urban Agglomerations, Census of India2001 and 2011
5. United States Environmental Protection Agency, (1991) b. National Air Policy and Emissions Trends Report, USEPA.
6. Senthilnathan T., (2007). Analysis of Concentration of Air Pollutants and Air Quality Index Levels in the Ambient Air in Chennai City, IE (I) Journal-EN, 87, 3-7.
7. Kenneth, T.K., (1994). On-road vehicle emissions: U S studies, The Science of the Total Environment, 146- 147(23): 209–215.
8. Miller, W., Collins, M.G., Steiner, F.R., and Cook, E., (1998). An approach for greenway suitability analysis. Landscape and Urban Planning 42, 91–105.
9. Urban Greening Guidelines, 2014
10. Weng, Q.; Rajasekar, U.; Hu, X. Modeling urban heat islands and their relationship with impervious surface and vegetation abundance by using ASTER images. IEEE Trans. Geosci. Remote Sens. 2011, 49, 4080–4089
11. Amiri, R.; Weng, Q.; Alimohammadi, A.; Alavipanah, S.K. Spatial–temporal dynamics of land surface temperature in relation to fractional vegetation cover and land use/cover in the Tabriz urban area, Iran. Remote Sens. Environ. 2009, 113, 2606–2617.
12. Mohajerani, A.; Bakaric, J.; Jeffrey-Bailey, T. The urban heat island effect, its causes, and mitigation, with reference to the thermal properties of asphalt concrete. J. Environ. Manag. 2017, 197, 522–538.
13. Amiri, R.; Weng, Q.; Alimohammadi, A.; Alavipanah, S.K. Spatial–temporal dynamics of land surface temperature in relation to fractional vegetation cover and land use/cover in the Tabriz urban area, Iran. Remote Sens. Environ. 2009, 113, 2606–2617.
14. Estoque, R.C.; Murayama, Y. Monitoring surface urban heat island formation in a tropical mountain city using Landsat data (1987–2015). Isprs J. Photogramm. Remote Sens. 2017, 133, 18–29.