Surface Urban Heat Island effect of a polynuclear mega city Delhi

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Abstract

Delhi has been built over centuries on unique urban planning concepts. This resulted in a polynuclear mega city comprising of organic city, garden city and new towns. The paper aims to test the new notion of dense cities with mix-land use on the thermal climatic scale.Three sub-cities have been selected built over the last 400 years. Surface heat island intensity in Local climate zones estimates the thermal effect. Space syntax and space-matrix are used to assess the socio-economic impact of morphology.

Introduction

Urbanization is bound to have climatic ramifications due to its interference with the surface energy balance. The urban form and function essentially characterize the climate of the city. A sustainable urban city has to strike balance between its morphometric and climatic performance. Delhi is presently the second most populated with 26 million people but by 2030 it will be the most populated urban area in the world.

Figure 1: World's Largest Cities (UN DESA 2018)

Conclusion

Lutyen's garden city performs well thermally but density is poor. Organic city is the most dense city with thermally higher score. New modern sub-city of Dwarka is denser, but thermally experiences a high range. The dense cities with mix-land use performs equivalent to organic city on thermal scale. Thus, the energy balance needs to be modeled to inquire further.

Future Work

Seasonal canopy layer air temperature is being collected using TH sensor setup in the Local Climate Zones of each sub-city to estimate Canopy layer Urban Heat Island Intensity.

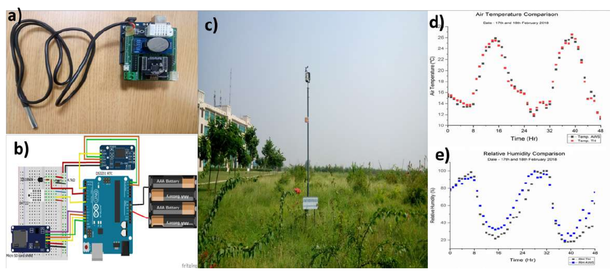


Figure 6: Canopy layer UHI a) Sensor Setup b) PCB diagram c) Calibration d) Temperature error e) Humidity error

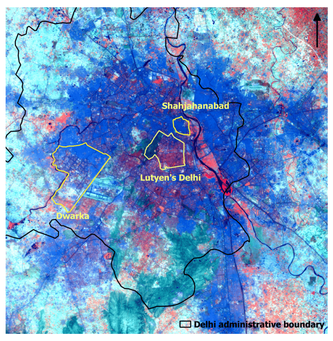
To understand the changes cause in energy balance, a basic SUEWS model is being run.

References

1. Ye, Y. E., and Van Nes, A. (2014). The spatial flaws of new towns.
2. World Urban Database Portal - Local Climate Zones (http://www.wudapt.org/lcz/).
3. UNESCO, World Heritage Centre (2012). Delhi – A Heritage City (Re. 5743).

Thermal and Morphological Evaluation of Three Sub-cities

Three sub-cities namely Shahjahanabad (1638) built on organic design as the capital of Mughal empire; Lutyen's Delhi(1911) built as the capital of British empire and inspired by the Garden city movement; and Dwarka (1992) built on the mixed-land use concept have been selected to test the notion. Seasonal Land Surface Temperature has been calculated in the Local Climate Zones of each sub-city to estimate Surface Urban Heat Island Intensity for the year 2015. Space Syntax maps are produced using Depthmap with angular radii to understand road integration. Also, Spacematrix (FSI, GSI and N) is computed to understand built density and compactness of city.



Aspects	Shahjahanabad	Lutyen's Delhi	Dwarka sub-city
Time Period	1638-1648	1911-1931	1992
Age of city	369 years old	86 years old	25 year old
Town planning	Organic Design	Geometric design	Mixed Land use concept
Important buildings	Red Fort and Jama Masjid	Connaught Place, Rashtrapati Bhavan, India Gate	
Area (km^2)	5.64	25.57	55.90
Population (Census 2011)	14,00,000 (Chandni Chowk Tehsil)	80,622 (Tehsil – Parliament street and Connaught place)	11,00,000
Population Density (people/km^2)	2,48,227	3,153	19,678
Road Length (km)	99.78	326.43	480.47
Road length (%)	17.66	12.76	8.59
LCZ Composition	Compact low-rise (42.98 %) Open mid-rise (32.6%) Large low-rise (12.16 %) Sparsely built (8.19 %) Scattered trees (2.74 %) Water (0.99%) Low plants (0.29%)	Open mid-rise (53.74 %) Scattered trees (19.14 %) Dense trees (17.08 %) Sparsely built (9.19 %) Large low-rise (3.58 %) Open low-rise (0.83 %)	Open mid-rise (53.21 %) Compact low-rise (20.05 %) Sparsely built (13.61 %) Low plants (11.79 %) Compact mid-rise (0.41 %) Heavy Industry (0.41 %) Bush (0.5 %)

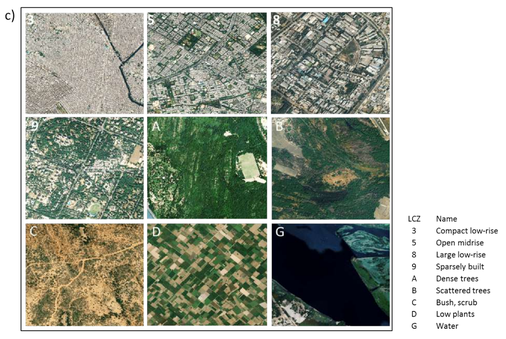


Figure 2: a) Study Area - Delhi with three sub-cities b) Table - Aspects of three cities c) Local representation of LCZ

Figure 3: a) Shahjahanabad b) Lutyen's Delhi c) Dwarka

Results

Maximum SUHI intensity has been observed in the month of May within the sub-city of Dwarka LCZ 5-LCZ D = 7.41°C, Lutyen's Delhi LCZ 5-LCZ A = 4.02°C and Shahjahanabad LCZ 8-LCZ B = 3.52°C. Space syntax values are highest in Dwarka indicating a good integration in sectors, followed by Lutyen's Delhi and Shahjahanabad. In terms of density, organic city has the highest FSI and GSI. Dwarka has a greater FSI than Lutyen since it has mid-rise structures as compared to low-rise buildings in Lutyen's Delhi. GSI for both the sub-cities are comparable as Dwarka still has some agricultural land.

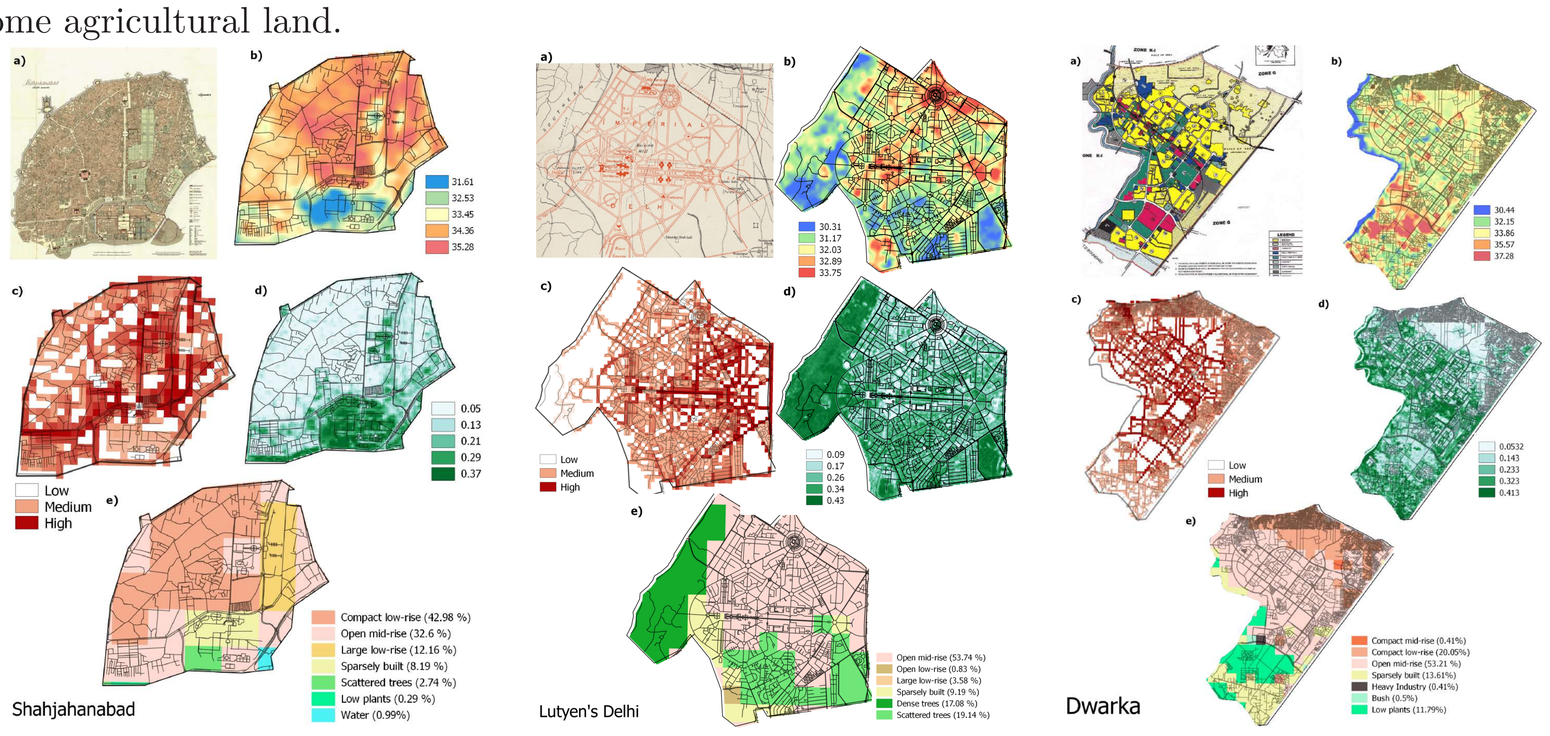


Figure 4: Aspects of three sub-cities a) Planning maps b) Land Surface Temperature (°C) c) Space Syntax d) Normalized Difference Vegetation Index e) Local Climate Zones composition

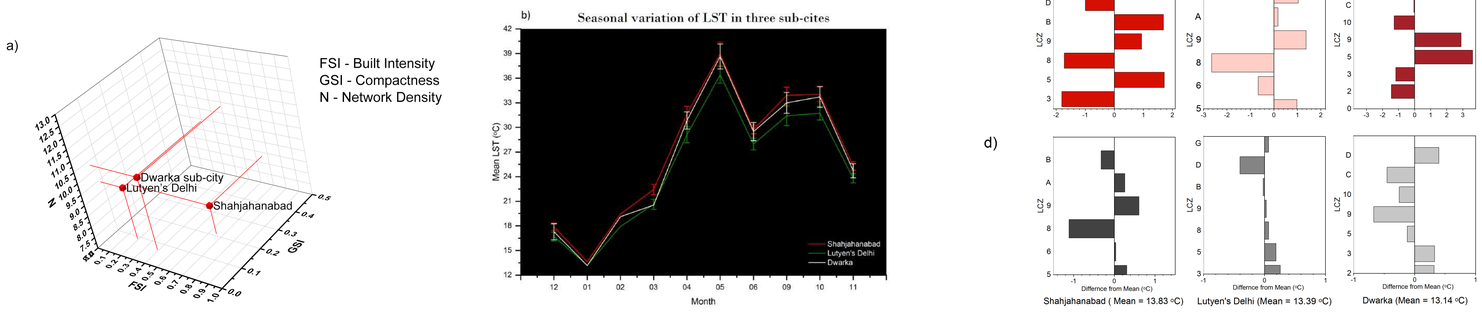


Figure 5: a) Spacematrix (FSI, GSI and N) b) Seasonal variation of LST in three sub-cities c) Inter LCZ SUHI intensity in Summer d) Inter LCZ SUHI intensity in Winter