Research Journal of Environmental and Earth Sciences 3(2): 75-80, 2011
ISSN: 2041-0492

Received: August 24, 2010 Accepted: October 06, 2010 Published: March 05, 2011

Classifying Urban Climate Field Sites by "Thermal Climate Zones" the Case of Onitsha Metropolis

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Abstract: The study is about testing the first phase of the new urban climate zoning scheme. The idea behind this work is to test this scheme in a city that is in the developing world with all its antecedent environmental and planning problems. This research tried to demonstrate a possible new approach to site classification using a system of "Thermal Climate Zones", and these zones were tested using the "urban" and "mixed" field sites in Onitsha metropolis. The results show that Onitsha sites correspond well with Thermal Climate zones; the zones observed include TCZ2 (old core), TCZ 3 (compact housing), TCZ 5 (Blocks), TCZ 6 (extensive lowrise), TCZ 7 (Regular housing), TCZ 8 (shanty town), TCZ 9 (open grounds) and TCZ 20 (dispersed settlements). Moreso, the major difference observed by the researcher is the difference in surface cover in some categories or zones. The new system provides a more useful interpretation of the landscape for urban climatologists. With further refinement, Thermal Climate Zones can improve consistency and accuracy in urban climate reporting.

Key words: Landscape classification system, onitsha metropolis, thermal climate zones, urban and rural

INTRODUCTION

The effect of urbanization on the microclimate of cities are mostly due to the changes in the various land uses to which urban areas are been put to, especially when these cities are compared to their surrounding countryside. Numerous investigations have thus, shown that rapid urbanization with artificial surfaces replacing natural land significantly modify the micro- and meso-scale flow fields of the cities (Bornstein, 1987). However, these investigations are plagued by inconsistency in the scale and methods used for site description, and to this Stewart (in press) in his review of modern heat island literature noted that completeness of reporting was an area that was very weak in urban heat island studies. Stewart attributed this to the tendency of heat island investigators to attach inappropriate or insufficient site metadata to their reports is the primary cause of this weakness.

The traditional ad hoc approach to site description used by many researchers has created much confusion in urban climate literature, as inter-city comparisons of results are rarely substantiated by the physical properties of the urban and rural field sites. Oke (2006) pointed out that although the use of common scales and techniques in urban climatology has greatly improved communication, the aspect of communication not yet standardized is the description of urban and rural field sites. To this, Ellefsen (1990/1) and Oke (2004) developed the first comprehensive classification systems for characterizing the urban environment. Ellefsen and Oke's classification scheme provided the necessary groundwork for a more universal scheme later proposed by Oke (2006) and Stewart and Oke (2009a). This scheme has since become the thermal climate zone classification system and it is the scheme used for this research. Although this scheme is still being perfected, it has been sampled in different parts of the world, especially the developed world (Stewart and Oke, 2010), and this research is aimed at doing same for a city in the developing country.

Thermal climate zones: Thermal Climate Zones (TCZ) are defined as regions of relatively uniform surface-air temperature distribution across horizontal scales of 10^2 to 10^4 m (Stewart and Oke 2009a, b). The zones are differentiated on surface properties that directly influence temperature climate, such as built surface fraction, building height-to-width ratio (H/W), Sky View Factor (SVF), height of roughness elements (Z_H), anthropogenic heat flux (QF), and surface thermal admittance (μ). By these differentiating properties, the 'urban-rural' continuum is reduced to 20 generic classes, or 'zones', that broadly represent the range of sites used in urban climate field studies (Fig. 1). The TCZ system consists of four series: 'city' (Fig. 2), 'mixed', 'agricultural' and 'natural'.

Scale is paramount in the classification process, especially in parameterizing field sites. All field sites are essentially defined by a "circle of influence" (also known as source area or footprint) whose radius extends from meters to kilometers depending on instrument height,

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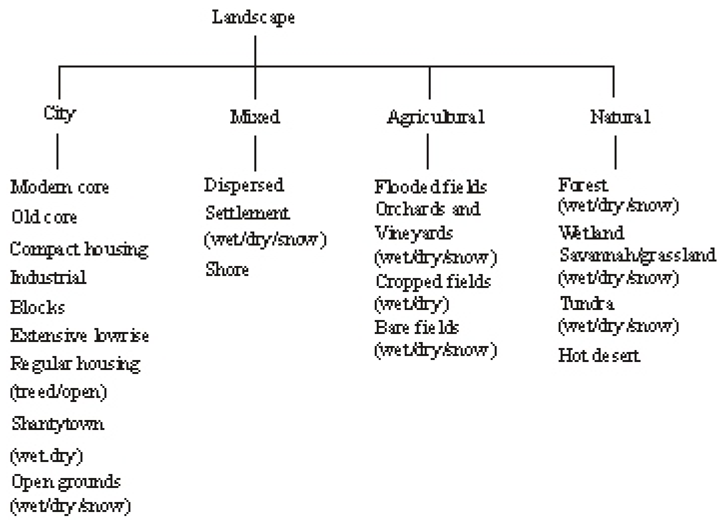


Fig. 1: showing the general classification of the TCZ (source: Stewart and Oke, 2009a)

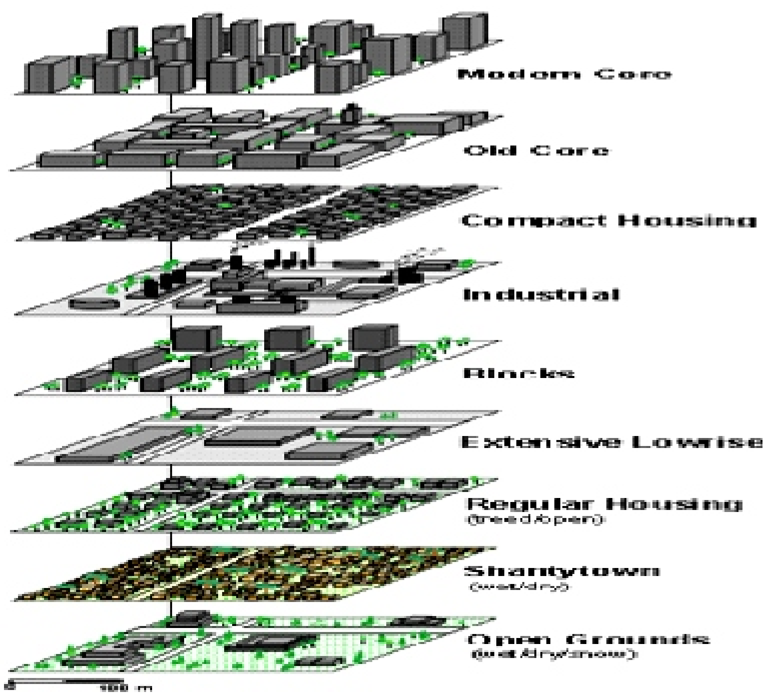


Fig. 2: Is the graphical representation of city series of the TCZ (source: Stewart and Oke, 2009a)

boundary-layer conditions, and surface geometry (Oke, 2004, 2006). Temperature measurements at shelter height (1-2 m agl) and among compact buildings, for example, are representative of smaller 'circles of influence' than measurements high above open fields. The spatial dimensions of the local climate zones are therefore flexible to the measurement conditions imposed by the site, and to the measurement set-up of a particular urban climate investigation.

MATERIALS AND METHODS

Data collection: The data required for the classification of the regional setting of Onitsha Metropolis and the structural characteristics of its field sites was obtained through field study conducted from 1st February to 30th March, 2010. Onitsha, a metropolis in south Eastern Nigeria, is located on the bank of River Niger. It is located between Longitude 06º05′28.90″N to

Table 1:

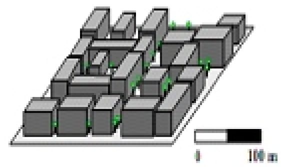
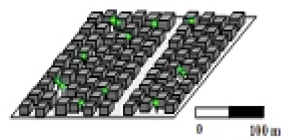
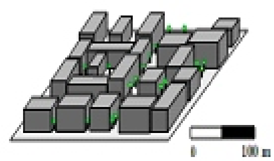
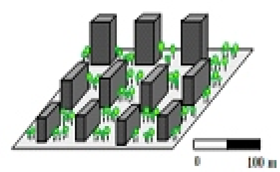
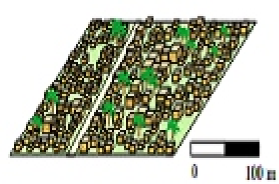
Site	Site Photograph	Thermal Climate Zone	Zone properties		
			SVF[1]	%built[2]	QF
1.Upper lweka		old core (TCZ 2)	0.5-0.8	>80	30-50
			Buildings are often large and dense, attached or close-set, and homogeneous in character with wide streets. Heavy traffic flow.		
2. Awadalayout		Compact housing (TCZ 3)	0.4-0.7	>70	20-30
			Buildings densely packed and are 2-4 stories tall. Light traffic flow. Construction materials heavy.		
3. Ochanja		Old core (TCZ 2)	0.4-0.6	>80	30-60
			Buildings are often large and dense, attached or close-set, and homogeneous in character with wide streets. Heavy traffic flow.		
4. Nkpor		Blocks (TCZ 5)	0.6-0.9	0.5-0.8	20-35
			Buildings uniform in design (height, width, materials). Abundance of trees and open space among buildings. Light traffic flow.		
5. Okpoko		Shantytown (wet) (TCZ 8)	0.7-0.9	>65	<5
			Buildings small and fragile, densely packed, separated by narrow streets and alleyways. Mostly unpaved, swampy compacted surfaces.		

Table 1: (Continued)

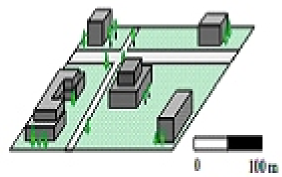
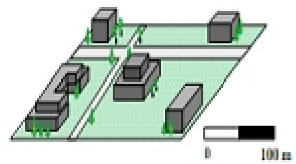
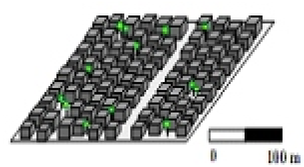
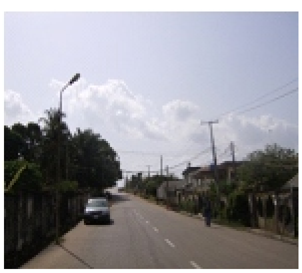
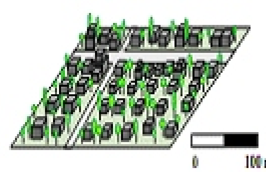
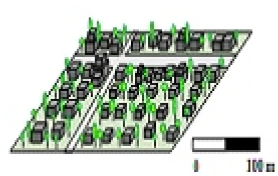
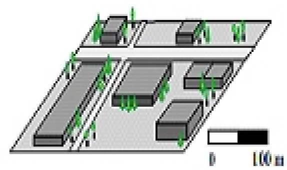
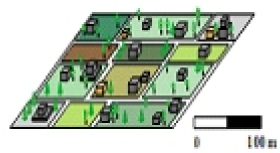
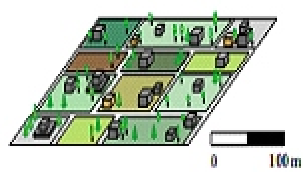
Site	Site Photograph	Thermal Climate Zone	Zone properties SVF[1]	%built[2]	QF
6. Stadium		Open grounds (dry) (TCZ9)	0.8-0.9	30-40	5-10
			Large, widely set midrise buildings in open, natural surroundings. Buildings vary in size, distribution, and height; with abundant vegetation.		
7. All Saints		Open grounds (dry) (TCZ9)	0.8-0.9	30-40	5-10
			Large, widely set midrise buildings in open spaces. Buildings vary in size, distribution, and height; with abundant trees.		
8. New parts		Compact housing (TCZ 3)	0.4-0.7	>70	20-30
			Buildings densely packed and are 2-4 stories tall. Light traffic flow. Construction materials heavy.		
9. Niger Drive		Regular housing (TCZ7)	0.6-0.8	40-70	10-15
			Low-rise buildings (1-3 stories), detached. Buildings separated by yards, and set along medium-width streets. Light traffic flow.		
10. Premier housing estate		Regular housing (TCZ7)	0.6-0.8	40-70	10-15
			Low-rise buildings (1-3 stories), detached and attached in rows. Buildings separated by yards, and in grid pattern. Light traffic flow.		

Table 1: (Continued)

Site	Site Photograph	Thermal Climate Zone	Zone properties SVF[1]	%built[2]	QF
		Extensive lowrise (TCZ6)	0.80-0.95	>60	30-50
11. Iyiowa indutrial estate			Flat, horizontal skyline of low- or mid-rise buildings and well separated by open, paved spaces. Moderate-high traffic density.		
		Dispersed settlement (TCZ20)	>0.80	<30	<2
12. Ziks Roundabout			Lowrise with abundant vegetation. Light-moderate traffic density.		
		Dispersed settlement (TCZ20)	>0.80	<30	<5
13. NOCE Nsugbe			lowrise. Built pattern lacks discernable form. Light traffic density.		

06º11′11.00″N, and Latitudes 06º45′20.75″E to 06º50'48.95"E; with its altitude rising from 50m (from its lowest points along the banks of the River Niger) to about 200m above mean sea level. Based on 2006 national census, Onitsha metropolis had an estimated population of 900,070 persons (www.nigerianstat.gov.ng/ Connections/ Pop2006.pdf). Quantitative site metadata obtained include building height to width (where applicable), sky view factor, fractional building cover, and soil thermal admittance. Maps, photographs, and surface measurements were obtained directly from the field studies. Away from the field, additional metadata were obtained from online portals for digital mapping and satellite imagery, such as Google Earth,© and from measurement, modelling, and classification studies of landscapes similar to those of Onitsha metropolis (e.g., Stewart and Oke, 2009b).

Methods: The sites and settings of urban climate observation are remarkably diverse, from small towns to sprawling cities, and from street canyons to building rooftops. Much less diverse, however, are the descriptions of the sites and settings used in urban climate studies (Stewart and Oke, 2009b). The spatial dimensions of the local climate zones are flexible to the measurement conditions imposed by the site, and to the measurement set-up of a particular urban climate investigation. Using a radius of 200 m, the source area of each field site was parameterized by the differentiating properties of the TCZ classes. The TCZ that best matched the measured or estimated properties of a field site was then identified. Different photographs alone substantiated reasonably accurate matches between field sites and TCZs, since a direct relation between the measured properties and the zone datasheets ultimately supported a more objective and reproducible outcome. The most important properties considered in this process were built surface fraction and building height-to-width ratio, surface thermal admittance.

RESULTS

These following categories were observed and some of their characteristics are documented in Table 1. The table shows that the zones observed include TCZ2 (old core), TCZ 3 (compact housing), TCZ 5 (Blocks), TCZ 6 (extensive lowrise), TCZ 7 (Regular housing), TCZ 8 (shanty town), TCZ 9 (open grounds) and TCZ 20 (dispersed settlements).

Like all classifcation systems, the TCZ scheme serves only as a general guide. Therefore, the best-not exact-match for each field's site was sought using the information contained in the zone datasheets. If site metadata were incomplete or poorly aligned with the datasheets, the process of selecting "best fit" zones became one of skilled judgment, knowledge of the field site and discretion of the researcher rather than automated matching.

CONCLUSION

A detailed characterization of the metropolis shows that the study area consists of 8 different categories of the Stewart and Oke (2009a) TCZ characterization scheme. Some of the categories did not easily fit into these categories, as some of the conditions set could not easily be met. Therefore, the researcher concentrated the categorization on aerial, street view and skyview photographs, height to width ratio were applicable, surface coverage, nature of surface, nature of building materials and other descriptions given to such categories or zones, which include function of such zones. The major difference observed by the researcher is the difference in surface cover in some categories or zones. Stewart and Oke (2009a) specified a higher level of impermeable surface than what was obtainable in these categories. This can be attributed to the level of development within the study.

IMPLICATIONS

Using local climate zones to classify the landscape offers an improvement over traditional "urban-rural" classification. The zones are suitably detailed to the site properties that influence near-surface climate, and they communicate these properties in clear, standardized format. Substantiating inter-city and cross-seasonal differences in surface-layer climate is a useful application of the system. UHI magnitude, for instance, is expressed more objectively through inter-zone temperature differences than through arbitrary urban-rural differences (Stewart and Oke, 2009). If UHI magnitude is defined in this way, it becomes a more robust indicator of urban climate modification than existing indicators like Tu-r. The temptation to interpret inter-city differences in UHI magnitude through surrogates like population or land use is less enticing if the surface properties that control UHI formation are implicit in the site classification system.

ACKNOWLEDGMENT

We are indebted to Professor T.R. Oke and Iain Stewart from University of British Columbia, Canada for sharing and directing the classification process. We also thank Professor E.O. Iguisi and Dr. O.F. Ati from Ahmadu Bello University Zaria, Nigeria, for all their support, advice and thorough supervision throughout this study.

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