International Journal of Innovative Studies in Sociology and Humanities
ISSN 2456-4931 | Open Access | Volume 7, Issue 6, 2022
DOI: https://doi.org/10.20431/2456-4931.0706001

Mapping El Harrach (Algeria) into Local Climate Zones by GIS Methods

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Abstarct

It becomes necessary to develop an urban climate diagnostic tool, in order to improve the urban planning approaches, as well as the conception of new projects at the micro-scales. The development of this tool requires an urban understanding of each block. This study aims to classify the El Harrachblocks, by applying the "Local Climate Zones" approach, and using the Geographic Information System (GIS) methods. Thus, within the framework of this study, we will test the adaptability of this approach on El Harrach. The results show that this approach seems to be in agreement with our aims; while taking into account certain particular conditions. It will also allow us to provide the precise details on the urban knowledge of each block, which could beused as a basis for strategic studies, that help the actors of the agglomeration in the implementation, the monitoring and the evaluation of environmental and energy policies.

Key words: Environmental changes, local climate zones, urban block, geographic information system, El Harrach.

INTRODUCTION

We are living inan unprecedented period. Urbanization and anthropogenic activities contribute to climate change through changes in the Earth's atmosphere, which can lead to unexpected extreme and disastrous events (Betsill and Bulkeley, 2007).

Indeed, cities, neighbourhoods and urban blockshave extremely diverse morphological featuresthat affect the urban climate (Oke and Maxwell, 1975). It is now becoming strategic to deepen the understanding of the urban blocks' morphology and function, in order to develop rational urbanization approaches; allowing to mitigate the deleterious effects of urbanization and to support urban resilience (Cordeau, 2014).

For this purpose, Stewart and Oke have developed a climate-based classification system of urban and rural sites at local scale, named"Local Climate Zones" (LCZs). It aims to standardizethe description of surface conditions in urban and rural areas, and to facilitate the communication of site metadata; and the interdisciplinary transfer of urban climate knowledge (Stewart and Oke, 2012). This system is internationally recognized (Landes et al., 2020). It is qualified as an international referencefor the classification of urban and rural areas. LCZ maps become an emergenttoolin urban climate research. They potentially provide an objective framework for the assessment of urban form and function (Verdonck et al., 2017).

The urban climate community strongly supported this approach (Mhedhbi and Hidalgo 2017). Several studies have demostrated its importance and adaptability to the different contexts and countries of the World, such as: Villadiego et al. (2012) on Barranquilla (Colombia), Unger et al. (2014) on Szeged (Hungary), IAU îdF (2014) on the Île-de- France (cited by Cordeau, 2014), Mhedhbi and Hidalgo (2017) on the MENA area (Middle East and North Africa), Yihan et al. (2018) on Shanghai (China), Landes et al. (2020) on Strasbourg.

In this research, our case study focuses on the agglomeration of El Harrach. We will classify its blocks into LCZ types based on their geometric and land cover properties. This classification will allow us tofully understand the morphological characteristics of each block, its environmental impact and its vulnerability.

PRESENTATION OF CASE STUDY

The agglomeration of El Harrachcovers an area of 9.42 km². It is located in the Eastern suburbs of Algiers, around 14 km from the Capital. This agglomeration is divided into two parts by the banks of the El Harrach River. It is characterized by a warm, humid summer climate and a mild winter climate (Dib, 1993), as well as by a flat relief with slopes ranging from 0 to 3% (Figure 1).

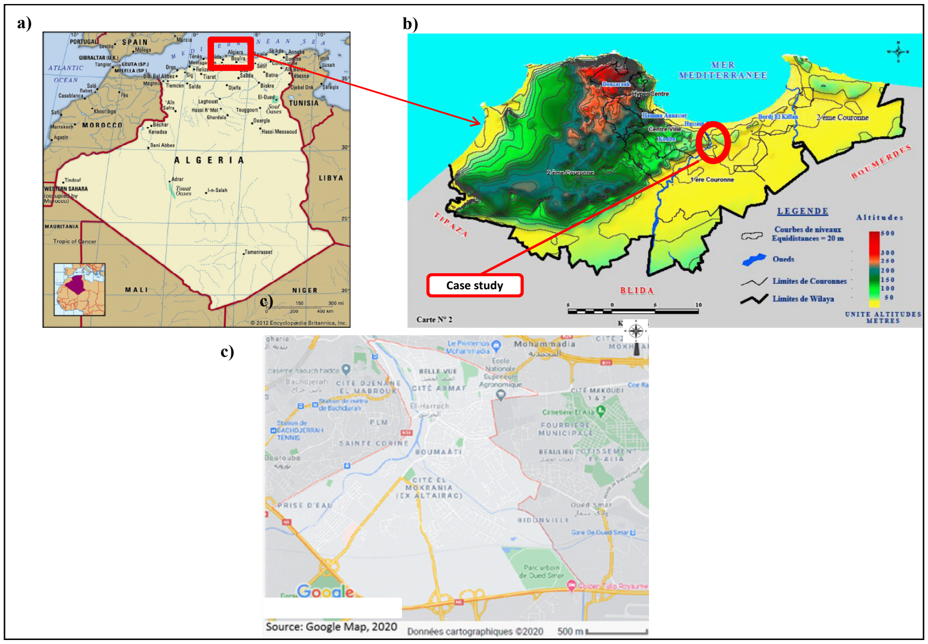


Figure 1. Geographical location of El Harrach: a) Geographial location of Algeria ; b) Algiers topography map ; c) Boundaries of El Harrach.(Source : https://www.britannica.com/; INCT cited by Tabti-Talamaliand Safar Zitoun, 2009 ; Google Map, 2020).

Within the framework of the review of Algiers urban planning and development master plan (approved in 2016), and through its strategic location, the agglomeration of El Harrachwas part of a large-scale territorial development project; that covers five agglomerations: El Harrach, Baraki, Gue de Constantine, Bourouba and the Eucalyptus (Figure 2). The intersection of these agglomerations represents the entrance and urban articulation of the Capital. Moreever, it is formed with the agglomerations of Bab Ezzouar and OuedSmar, the future competitiveness Algiers' cluster (Figure 3), mainly focused on building an attractive urban offer (Parque Expo, 2011).

However, El Harrach is most vulnerable to global warming because of (Bouattou, 2016): (i) its unfavourable climatic and geographic conditions, which restrict its natural ventilation and promote the capture of heat and pollution, (ii) unsustainable development practices and (iii) the concentration of anthropogenic activities that contribute to intense greenhouse gases emissions, such as: industry, transport and building. This critical situation could affect its attractiveness, environmental quality and comfort over the medium and long-term.

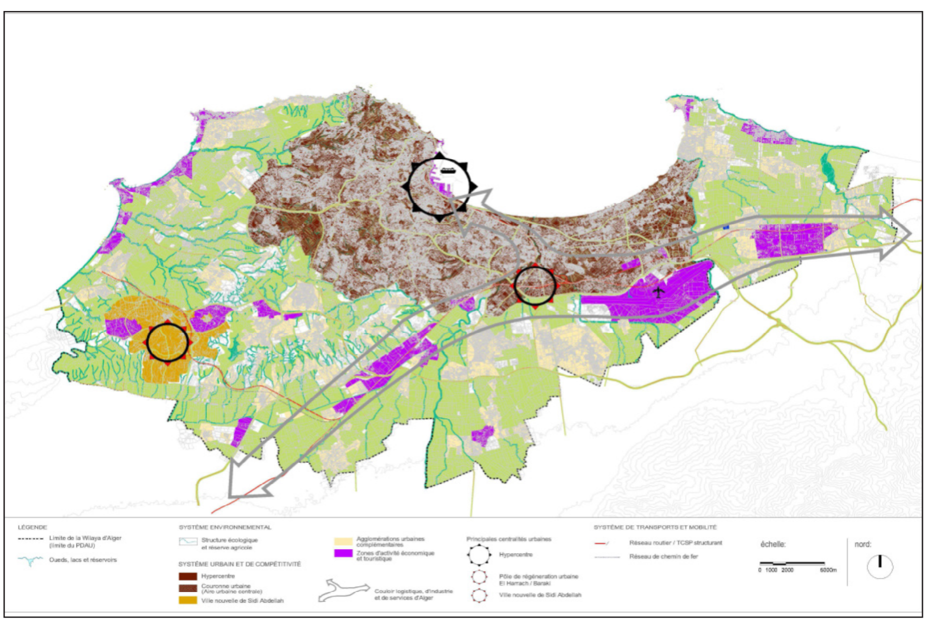


Figure 2. Territorial model of Algiers.(Source :Parque EXPO, 2011).

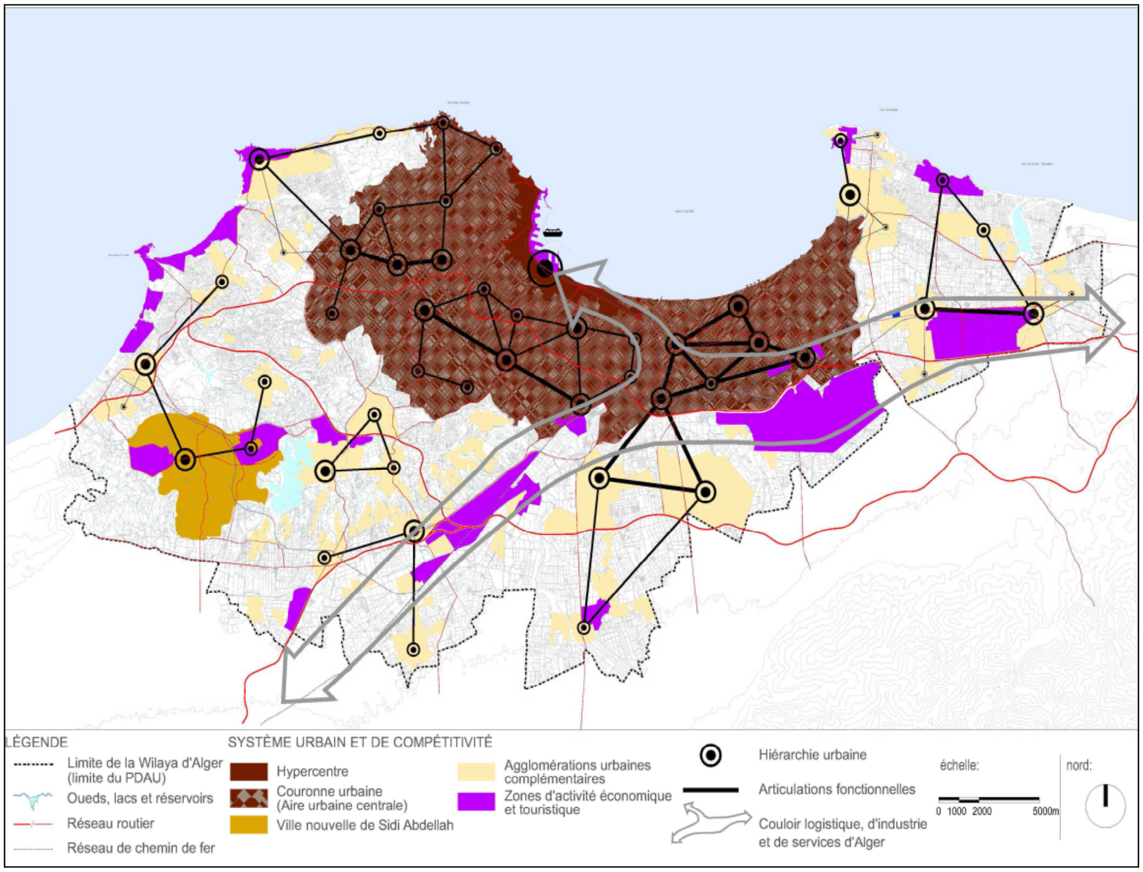


Figure 3. Urban system and competitiveness of Algiers. (Source :Parque EXPO, 2011).

METHODS AND MATERIALS

Local Climate Zones

Local climate zones are defined as uniform areas of surface cover (pervious and impervious), surface structure (height and density), building materials (heavy and light-weight) and anthropogenic activity (heat output)that span hundreds of meters to several kilometersin horizontal scale (Stewart and Oke, 2012).

Each LCZ exhibits a characteristic geometry and land cover that generates a specific local climate undercalm and clear sky (Stewart and Oke 2009). According to these characteristics, urban and rural areas are classified into 17 standard LCZs classes: 10 "built types" classes (1 – 10) and 7 "land cover types" classes (A- G) (Table 1). Built types consist of constructed features on a predominant landcover, which is paved for compact zones and low plants or scattered trees for open areas (Cordeau 2016).

This classification is mainly based on measurable physical properties which are nonspecific as to place or time. These properties characterize the surface geometry and cover, the construction materials and the anthropogenic heat emissions (Table 2).

Consequently, 17 illustrative LCZ datasheets have been generated. These sheets allow urban climate investigators to classify uniformly and effectively the landscapes and field sites (Stewart and Oke, 2012 Landes et al., 2020).

The LCZ classification system allows standardizing urban temperature observations. It also provides a basic package of urban climate, especially for: urban planners, architects, ecologists and engineers (Stewart et al., 2018). However, the LCZ system is inherently generic; it cannot capture the specifics of each urban and rural area. Its vision of the landscape universe is very reductionist and, like all classifications, its descriptive and explanatory abilities are limited (Stewart and Oke, 2012).

Table 1. Local Climate Zones (LCZ) classification system(Stewart andOke,2012).

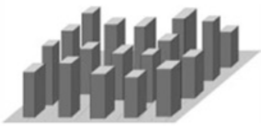
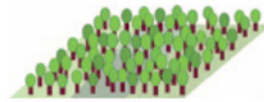
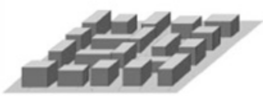
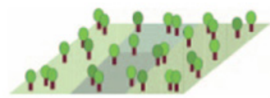
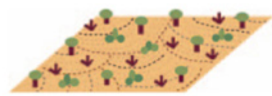
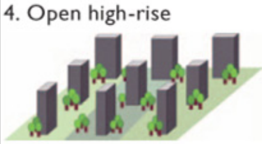
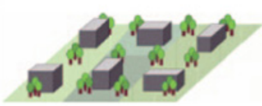
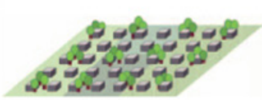
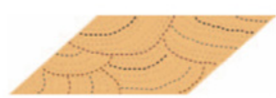
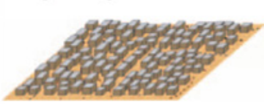
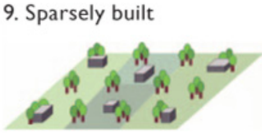
Built types	Definition	Land cover types	Definition
1. Compact high-rise 	Dense mix of tall buildings to tens of stories. Few or no trees. Land cover mostly paved. Concrete, steel, stone, and glass construction materials.	A. Dense trees 	Heavily wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
2. Compact midrise 	Dense mix of midrise buildings (3–9 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	B. Scattered trees 	Lightly wooded landscape of deciduous and/or evergreen trees. Land cover mostly pervious (low plants). Zone function is natural forest, tree cultivation, or urban park.
3. Compact low-rise 	Dense mix of low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Stone, brick, tile, and concrete construction materials.	C. Bush, scrub 	Open arrangement of bushes, shrubs, and short, woody trees. Land cover mostly pervious (bare soil or sand). Zone function is natural scrubland or agriculture.
4. Open high-rise 	Open arrangement of tall buildings to tens of stories. Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	D. Low plants 	Featureless landscape of grass or herbaceous plants/crops. Few or no trees. Zone function is natural grassland, agriculture, or urban park.
5. Open midrise 	Open arrangement of midrise buildings (3–9 stories). Abundance of pervious land cover (low plants, scattered trees). Concrete, steel, stone, and glass construction materials.	E. Bare rock or paved 	Featureless landscape of rock or paved cover. Few or no trees or plants. Zone function is natural desert (rock) or urban transportation.
6. Open low-rise 	Open arrangement of low-rise buildings (1–3 stories). Abundance of pervious land cover (low plants, scattered trees). Wood, brick, stone, tile, and concrete construction materials.	F. Bare soil or sand 	Featureless landscape of soil or sand cover. Few or no trees or plants. Zone function is natural desert or agriculture.
7. Lightweight low-rise 	Dense mix of single-story buildings. Few or no trees. Land cover mostly hard-packed. Lightweight construction materials (e.g., wood, thatch, corrugated metal).	G. Water 	Large, open water bodies such as seas and lakes, or small bodies such as rivers, reservoirs, and lagoons.
8. Large low-rise 	Open arrangement of large low-rise buildings (1–3 stories). Few or no trees. Land cover mostly paved. Steel, concrete, metal, and stone construction materials.	**VARIABLE LAND COVER PROPERTIES** Variable or ephemeral land cover properties that change significantly with synoptic weather patterns, agricultural practices, and/or seasonal cycles.	
9. Sparsely built 	Sparse arrangement of small or medium-sized buildings in a natural setting. Abundance of pervious land cover (low plants, scattered trees).	*b. bare trees* *s. snow cover*	Leafless deciduous trees (e.g., winter). Increased sky view factor. Reduced albedo. Snow cover >10 cm in depth. Low admittance. High albedo.
10. Heavy industry 	Low-rise and midrise industrial structures (towers, tanks, stacks). Few or no trees. Land cover mostly paved or hard-packed. Metal, steel, and concrete construction materials.	*d. dry ground* *w. wet ground*	Parched soil. Low admittance. Large Bowen ratio. Increased albedo. Waterlogged soil. High admittance. Small Bowen ratio. Reduced albedo.

Table 2. Physical properties characterizing the elements of the LCZ system (Stewart andOke, 2012).

Geometric and surface cover properties	Skyview factor
	Aspect ratio
	Building surface fraction
	Impervious surface fraction
	Pervious surface fraction
	Height of roughnesselements
	Terrain roughness class
Thermal, radiative, and metabolic properties	Surface admittance
	Surface albedo
	Anthropogenicheat output

Classification of El Harrach's blocks into Local Climate Zones –LCZ

The LCZ classification uses blocks metadata and satellite images to producedata about the surface's physical properties. These data constitute the type of each block, using a typology based on the local climate zone schema (Table 1). To create the climate zones of El Harrach by the classification of its blocks, we proceeded with the following steps:

Step 1: Delimitation and digitization of blocks on Google Earth Pro

We define and digitize the boundaries for each morphologically homogenous block in the El Harrach agglomeration, by using Google Earth Pro (Figure 4). Then they were saved in ".kml" file format, which was imported as shapefile to ArcGIS.

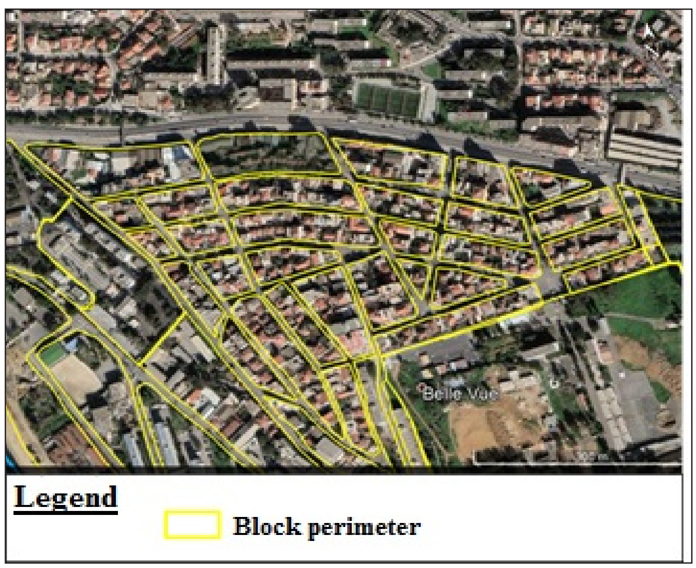


Figure 4. Delimitation and digitization of El Harrach's blocks

Step 2: Collect blocks metadata

Due to the lack of dataon thermal, radiative and metabolic properties in El Harrach, the geometrical properties and land cover metadata, of each block, are collected in this study. This collect is based on: (i) Our in-situ surveys; (ii) Satellite images (Google Earth Pro, Geopedia and Satellites.pro) and (iii) land use and building height maps; provided by: the urban planning and development master plan of Algiers 2016, the El Harrach City Hall and the Algerian-Korean design office.

Step 3: Calculation of geometric and land cover properties

In the present study, we calculated for each block six (06) fromthe seven (07) geometric and land cover properties, initially proposed by Stewart and Okein their classification system (Table 3). These properties are determined with vector and raster GIS methods, using mainly the collected data.

It is important to note that due to the complexity of calculating the sky view factor, which requires a combination of multiple software and a 3D database of each block's construction, this parameter was omitted from this study.

Indeed, the properties calculated in this work are:

a) Geometric properties:

– Aspect ratio

– Height of roughness elements

– Terrain roughness class

b) Surface cover properties:

– Building surface fraction

– Impervious surface fraction

– Pervious surface fraction

Table 3. Values of geometric and surface cover properties for local climate zones(Stewart and Oke, 2012).

Local climate zone (LCZ)	Sky view factor[a]	Aspect ratio[b]	Building surface fraction[c]	Impervious surface fraction[d]	Pervious surface fraction[e]	Height of roughness elements[f]	Terrain roughness class[g]
LCZ 1 *Compact high-rise*	0.2–0.4	> 2	40–60	40–60	< 10	> 25	8
LCZ 2 *Compact midrise*	0.3–0.6	0.75–2	40–70	30–50	< 20	10–25	6–7
LCZ 3 *Compact low-rise*	0.2–0.6	0.75–1.5	40–70	20–50	< 30	3–10	6
LCZ 4 *Open high-rise*	0.5–0.7	0.75–1.25	20–40	30–40	30–40	>25	7–8
LCZ 5 *Open midrise*	0.5–0.8	0.3–0.75	20–40	30–50	20–40	10–25	5–6
LCZ 6 *Open low-rise*	0.6–0.9	0.3–0.75	20–40	20–50	30–60	3–10	5–6
LCZ 7 *Lightweight low-rise*	0.2–0.5	1–2	60–90	< 20	<30	2–4	4–5
LCZ 8 *Large low-rise*	>0.7	0.1–0.3	30–50	40–50	<20	3–10	5
LCZ 9 *Sparsely built*	> 0.8	0.1–0.25	10–20	< 20	60–80	3–10	5–6
LCZ 10 *Heavy industry*	0.6–0.9	0.2–0.5	20–30	20–40	40–50	5–15	5–6
LCZ A *Dense trees*	<0.4	>1	<10	<10	>90	3–30	8
LCZ B *Scattered trees*	0.5–0.8	0.25–0.75	<10	<10	>90	3–15	5–6
LCZ C *Bush, scrub*	0.7–0.9	0.25–1.0	<10	<10	>90	<2	4–5
LCZ D *Low plants*	>0.9	<0.1	<10	<10	>90	<1	3–4
LCZ E *Bare rock or paved*	>0.9	<0.1	<10	>90	<10	<0.25	1–2
LCZ F *Bare soil or sand*	>0.9	<0.1	<10	<10	>90	< 0.25	1–2
LCZ G *Water*	>0.9	<0.1	<10	<10	>90	–	1

[a] Ratio of the amount of sky hemisphere visible from ground level to that of an unobstructed hemisphere

[b] Mean height-to-width ratio of street canyons (LCZs 1–7), building spacing (LCZs 8–10), and tree spacing (LCZs A–G)

[c] Ratio of building plan area to total plan area (%)

[d] Ratio of impervious plan area (paved, rock) to total plan area (%)

[e] Ratio of pervious plan area (bare soil, vegetation, water) to total plan area (%)

[f] Geometric average of building heights (LCZs 1–10) and tree/plant heights (LCZs A–F) (m)

[g] Davenport et al.'s (2000) classification of effective terrain roughness (z_0) for city and country landscapes. See Table 5 for class descriptions

Table 4. *Davenport classification of effective terrain roughness (Davenport, 2000).*

Davenport class	Roughness length, z_0 (m)	Landscape description	LCZ correspondence
1. Sea	0.0002	Open water, snow-covered flat plain, featureless desert, tarmac, and concrete, with a free fetch of several kilometers.	E, F, G
2. Smooth	0.0005	Featureless landscape with no obstacles and little if any vegetation (e.g., marsh, snow-covered or fallow open country).	E, F
3. Open	0.03	Level country with low vegetation and isolated obstacles separated by 50 obstacle heights (e.g., grass, tundra, airport runway).	D
4. Roughly open	0.10	Low crops or plant covers; moderately open country with occasional obstacles (e.g., isolated trees, low buildings) separated by 20 obstacle heights.	7, C, D
5. Rough	0.25	High crops, or crops of varying height; scattered obstacles separated by 8 to 15 obstacle heights, depending on porosity (e.g., buildings, tree belts).	5–10, B, C
6. Very rough	0.5	Intensely cultivated landscape with large farms and forest clumps separated by 8 obstacle heights; bushland, orchards. Urban areas with low buildings interspaced by 3 to 7 building heights; no high trees.	2, 3, 5, 6, 9, 10, B
7. Skimming	1.0	Landscape covered with large, similar-height obstacles, separated by 1 obstacle height (e.g., mature forests). Dense urban areas without significant building-height variation.	2, 4
8. Chaotic	≥ 2	Landscape with irregularly distributed large obstacles (e.g., dense urban areas with mix of low and high-rise buildings, large forest with many clearings).	1, 4, A

Source: Davenport et al. (2000)

- The aspect ratio was estimated from the average of the heights of the built elements on the average of the widths of the roads delimiting the block.
- The height of the roughness elements was determined from the El Harrach building height map.
- The impervious surface fraction was calculated from the ratio of the open impervious areas to the total area of the block.
- The building surface fraction was estimated from the ratio between the built-up areas and the total area of the block.
- The pervious surface fraction was calculated from the ratio of permeable open areas to the total area of the block.
- The terrain roughness class was determined by applying the Davenport roughness classification method (Table 4).

Step 4: Select the local climate zone

Based on the properties calculated in step 3, these values were compared to the standard LCZ classes, presented in Table 3. However, for certain blocks, the estimated values do not completely correspond to the standards. In this case, according to Stewart and Oke (2012): « the process of selecting a best-fit class becomes one of interpolation rather than straight matching».We have therefore classified these blocks bylooking attheir surface cover fractions,and identify the nearest LCZ classes.

RESULTS AND DISCUSSIONS

We havestudied 527 blocks; forming the agglomeration of El Harrach. These blocks have been classified and mapped to LCZ classes (figure 5).

The results showed that the agglomeration of El Harrach contains different LCZ classes. The predominant class is LCZ3 (Compact low-rise). However, LCZ1 class (compact high-rise) does not exist. It is important to note that military zones and construction sites have not been classified.

Thus, from this classification, we found that the calculated values of the geometric and surface cover properties mainly correspond to the standard LCZ classes giving in table 3.Nevertheless,some differences were noted in LCZ 10, LCZ 7 and certain LCZ 2; LCZ 3; LCZ 4; LCZ 8 . Thesedifferences are presented in table 5.

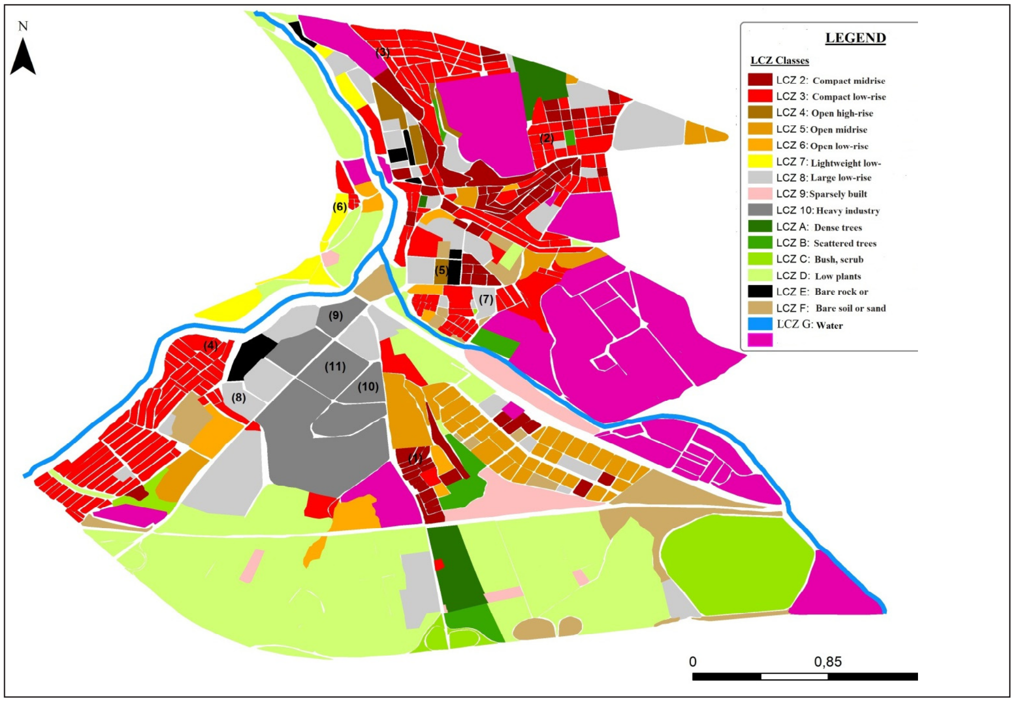


Figure 5. Local climate zones classification map of ElHarrach

For example:

- LCZ10 (Heavy industry): Its building surface fractionis higher than the upper limit.
- LCZ 7 (Lightweight low-rise): Its building surface fraction is under the lower limit.
- LCZ3 (compact low-rise): Its impervious surface fraction is lower than the inferior limit.

Table 5. Values of geometric and surface cover properties of some local climate zone in El Harrach

Classes LCZ		Aspect ratio	Height of roughness elements (m)	Terrain roughness class	Building surface fraction(%)	Impervious surface fraction (%)	Pervious surface fraction (%)
LCZ 2	**Reference zone**	0,75-2	10-25	6-7	40-70	30-50	< 20
	(1)	1,5	12,75	7	93,06	3,5	3,44
LCZ3	**Reference zone**	0,75-1,5	3-10	6	40-70	20-50	< 30
	(2)	0,9	10	6	84,37	9,38	6,25
	(3)	0,9	9	6	90,29	3,26	6,45
	(4)	1,4	10	6	85,85	11,01	3,14
LCZ4	**Reference zone**	0,75-1,25	> 25	7-8	20-40	30-40	30-40
	(5)	1	31,5	7	17,15	75,23	7,62
LCZ7	**Reference zone**	1-2	2-4	4-5	60-90	< 20	< 30
	(6)	0,6	7,5	4	38,88	34,43	26,69
LCZ8	**Reference zone**	0,1-0,3	3-10	5	30-50	40-50	< 20
	(7)	0,1	4,5	5	18,28	77,72	4
	(8)	0,2	6	5	30,04	68,15	1,81
LCZ10	**Reference zone**	0,2-0,5	5-15	5-6	20-30	20-40	40-50
	(9)	0,1	40	6	30,66	46,77	22,57
	(10)	0,2	5	6	32,05	58,02	9,93
	(11)	0,2	5	6	43,45	51,54	5,01

Villadiego et al., in their study about the classification of Barranquilla (Colombia) into LCZ in 2012. Indeed, the results of this research confirmed the adaptability of Stewart and Oke's referential classification to the case study. They have shown that there are values which correspond to the referential standards, as there are some deviations. For example, some LCZ1 in Barranquilla have an aspect ratio higher than the upper limit (Villadiego, 2012).

In the same context and in order to guide the selection for the LCZ class, Stewart and Oke (2012) have mentioned that the collected or estimated metadata should lead researchers to the best, not necessarily exact, match of their field sites with LCZ classes. If an appropriate match still cannot be found, they should acknowledge this fact and highlight the major difference(s) between their site and its nearest equivalent LCZ.

The differences between the standard LCZ classes and the estimated values have been also reported by

Furthermore, by comparing the LCZ classification map elaborated (Figure 5) with the El Harrach's land use map in 2005 (Figure 6), established by Bakour in 2006, we have observed the increase of urbanization in fertile areas by the construction of the building due to the high pressure of urban development.

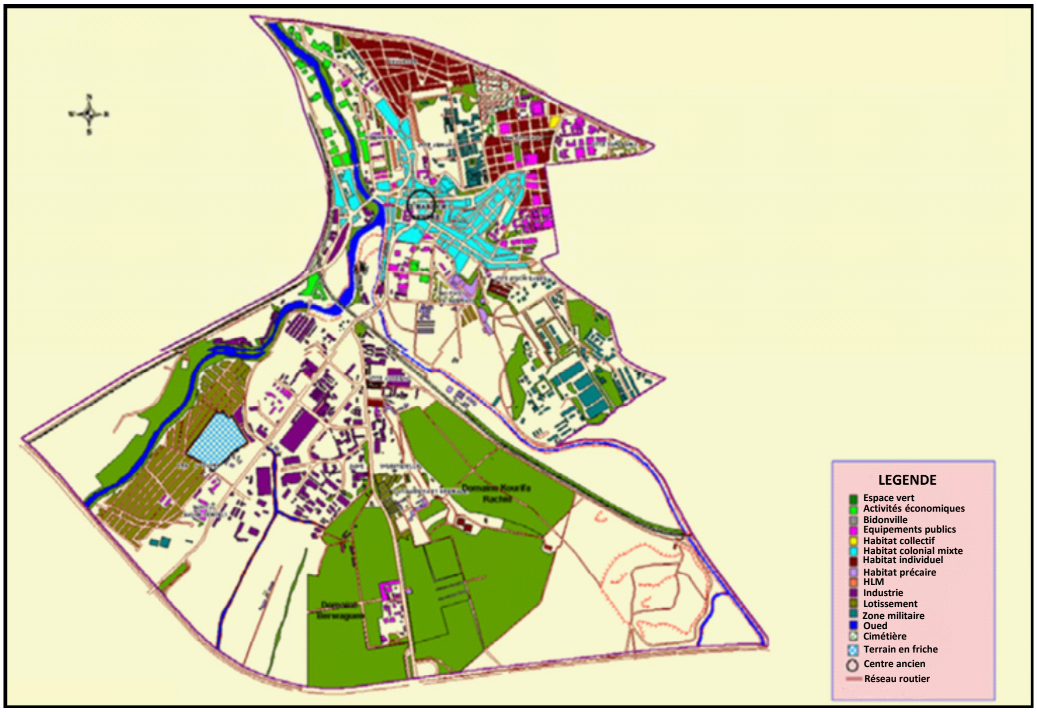


Figure 6. Land use map of El Harrach in 2005 (Bakour, 2006).

CONCLUSION

In this study, we determined the LCZ types in the agglomeration of El Harrach by using six geometric and surface cover properties; among the seven ones defined by Stewart and Oke (2012). The mapping of these classes showed that the agglomeration of El Harrachhas diverse LCZ classes, the most dominant is LCZ3 (Compact low-rise). Thus, this research allowed us to confirm the adaptability of this classification system to different countries and urban contexts, without ignoring the particularities of each context. It is important to note that the correspondence between blocks and LCZ classes will vary according to physical and cultural changes in the landscape, especially in active urban blocks where land clearance and development occur. Updating LCZ designations is crucial for these blocks. Sites situated on the edge of cities where urban growth and environmental change are rapid, or in the cores of cities where land redevelopment and large –scale greening projects are taking place, should be surveyed and classified after each operation.

Furthermore, the LCZ classification can meet the basic requirement in urban climate studies; through a standardized description of surface structure, function and cover. It can improve the description of surface conditions in urban and rural areas, as well as facilitate the process of site selection and metadata reporting.

This classification can be used to characterizethe environmental and climatic issues in urban areas. It can also support low environmental impact urban planning and development projects.

ABBREVIATIONS

INCT National Institute of Cartography and Teledetection

Kml KeyholeMarkupLanguage

LCZ Local Climate Zones

GIS Geographic Information System

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Citation: *Asma Bouattou, Aissa Mahimoud. et al. Mapping El Harrach (Algeria) into Local Climate Zones by GIS Methods. Int J Innov Stud Sociol Humanities. 2022;7(6):01-11. DOI: https://doi.org/10.20431/2456-4931.0706001.*