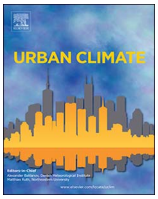
Urban Climate 24 (2018) 153–174

Contents lists available at ScienceDirect

Urban Climate

journal homepage: www.elsevier.com/locate/uclim



A geoprocessing framework to compute urban indicators: The MApUCE tools chain

Erwan Bocher[a,*], Gwendall Petit[b], Jérémy Bernard[a], Sylvain Palominos[a]

[a] *CNRS, Lab-STICC laboratory UMR 6285, Vannes, France*
[b] *Université de Bretagne Sud, Lab-STICC laboratory UMR 6285, Vannes, France*

ARTICLE INFO

Keywords:
Morphological indicators
Local climate zone
GIS
Urban Heat Island
Open source

ABSTRACT

A growing demand from urban planning services and various research thematics concerns urban fabric characterization. Several projects (such as WUDAPT) are currently lead in the urban climate field to answer this demand. However there is currently a need to propose standardized methods to calculate urban indicators and to automatically classify the urban fabric for any city in the world as well as to propose platforms to share these methods and the associated results. Our contribution answers partially to this challenge. A total of 64 standardized urban morphological indicators are calculated for three scales of analysis: building, block and a reference spatial unit (RSU). A supervised classification is performed for the building and the RSU scales using a regression trees model based on these indicators and on 10 urban fabric typological classes defined by urbanists and architects. A processing chain is proposed to realize indicator calculation and urban fabric classification for any french municipality according to reference data provided by the French National Geographical Institute (IGN). Spatial reasoning and morphological indicators description are formalized with SQL language and statistical analysis is carried out with R language. Finally a geoprocessing framework based on free and open source softwares, conform to the Open Geospatial Consortium (OGC) standards and ready to serve open data is built. Indicators values and classification results for 6% of the french municipalities (corresponding to 41% of all french buildings) are available through a web cartographic portal by any person interested in such analysis.

1. Introduction

According to the Intergovernmental Panel on Climate Change (IPCC) projections, global surface temperature will increase during the XXIst century. In the meantime, the world population living in cities is expected to grow (5058 millions by 2030 against 4250 millions in 2018 - Nations, 2015). Two factors explain this number: the population of existing cities will grow, and new cities will appear. Urbanization often implies urban temperature rise due to land cover change (pervious to impervious ground Levermore et al., 2017; He et al., 2007) and morphology change (new buildings mean more short and long-wave radiation trapping as well as wind speed decreasing Chen et al., 2012). Without urbanization control, this phenomenon called Urban Heat Island (UHI) may become more intense since temperature differences between an urban area and its surrounding is proportional to the logarithm of its population (Oke, 1973; Park, 1986). The combination of climate change and UHI may lead to higher heat related death occurrence (Conti et al., 2005; Laaidi et al., 2012) and higher energy consumption related to cooling use (de Munck et al., 2013; Hirano and Yoshida, 2016). Therefore, the reduction of the urban heat island phenomenon may contribute both to attenuate the climate change

---

[*] Corresponding author.
E-mail address: erwan.bocher@univ-ubs.fr (E. Bocher).

https://doi.org/10.1016/j.uclim.2018.01.008
Received 21 July 2017; Received in revised form 10 January 2018; Accepted 28 January 2018

(by reducing urban greenhouse emissions) and to mitigate its impacts. Several levers have proved their efficiency to lower urban air temperature such as surface painting to modify the albedo, planting trees or covering roofs and facades with low vegetation, decreasing energy consumptions, *etc.* (Kikegawa et al., 2006; Santamouris et al., 2017). Santamouris et al. (2017) showed that their performance and surface application potential differ greatly depending on the urban environment where they are applied in. To study the influence of urban morphology and urban land-cover on urban air temperature as well as the efficiency of each UHI countermeasure, urban climate models have been developed (Grimmond et al., 2010) and urban classification have been proposed (Stewart, 2011). Urban climate models are applied to a grid of urban mesh. For each mesh, several urban parameters are needed such as mean building height, aspect ratio, etc. Concerning the urban classification, the territory is also split into elementary units which are then classified according to a Local Climate Zone (LCZ) definition based on urban parameters describing urban morphology, urban land-cover, urban land-use and material properties (Stewart and Oke, 2012). Research has been made to identify LCZ within urban areas from geographical data. Most of the methods are based on a process using three steps. First the territory is split according to a certain grid. Second, urban parameters are calculated within each mesh from vector database or satellite images. Third, rules are created to allocate each mesh to a LCZ. Each of these steps may be manually (Leconte et al., 2015) or automatically (Lelovics et al., 2014; Zheng et al., 2017) performed. The limitations of those works is their lack of reproducibility. The manual classification is time-consuming and based on expert analysis. The automatic classifications proposed by Lelovics et al. (2014) and Zheng et al. (2017) rely on local data and on their own urban indicator definition. Thus simulation and classification approaches are very sensitive to data and methodology used to calculate urban indicators (characteristic of the morphology and the land cover of the urban fabric) (Tornay et al., 2017a). To obtain comparable indicators at world scale, there is a need:

- to standardize data and methodology used for urban indicators calculation (Mills et al., 2015),
- to propose collaborative and open tools to allow any user to calculate urban indicators for the city of its choice, thus allowing to share and reuse results from any calculation.

In this spirit, a collaborative project called *World Urban Database and Access Portal Tools* (WUDAPT[1]) gathers a community of researchers to classify the urban fabric by climate properties from homogeneous and available data at world scale. The objective is to identify Local Climate Zones as defined by Stewart and Oke (2012). The first step of the project have been applied. The LCZ of several urban areas have been identified according to supervised machine learning method using Landsat images (30 m resolution) as input and LCZ identified by climate expert from Google Earth software as desired output (Bechtel et al., 2015). However, WUDAPT is open to improvements:

- the need to install locally several softwares (Google Earth[2], SAGA[3]) on its computer may be a break to collaborative contribution,
- it is now necessary to provide data and urban indicators at finer scale (Mills et al., 2015). Plenty of indicators exist but they have several definitions and they are implemented within different softwares using numerous languages and methods. Thus comparing the value of such undefined indicator throughout the world or along time is impossible (Böhringer and Jochem, 2007).

Our contribution consists in the production of standardized urban morphological indicators dedicated for urban climate and useful for any other urban planning purpose. It is a component of a french research project called MApUCE[4] and is encompassed in a task of urban tissue characterization, illustrated in Fig. 1.

Input data are produced from reference data. They are used to produced both morphological and socio-economic indicators, that will be used to classify the urban fabric into typological classes. In this article, we will focus on the morphological indicators production and we will described briefly the classification step. Further details concerning the input data production and the socio-economic indicators production are available in Plumejeaud-Perreau et al. (2015) whereas the classification process is further described in Faraut et al. (2016) and Masson et al. (2016). Because one of the objective is that the overall process be reproducible simply without any software requirement, this paper proposes an open geoprocessing framework based on free and open source softwares, conform to the Open Geospatial Consortium standards and ready to serve open data.

2. Data

2.1. Scale definition

Whereas streets may be considered as more durable than blocks and buildings (Oliveira, 2016), building is the elementary object structuring the territory (Steiniger et al., 2008) and also the object of interest when focusing on urban climate application (Oke, 1987). However, building scale is not appropriate when dealing with issues at city scale. For this reason, Berghauser-Pont and Haupt (2005) proposed five scales to analyze urban areas: buildings, lots, island, fabric and district. The first described only building properties whereas the others described the building properties and their surrounding environment. Lots are defined by the legal

---

[1] http://www.wudapt.org/ accessed in July 2017.

[2] https://www.google.com/earth/ accessed in July 2017.

[3] http://www.saga-_gis.org/ accessed in July 2017.

[4] http://www.umr-_cnrm.fr/ville.climat/spip.php?rubrique120 accessed in July 2017.