Development of an Interactive Time-Series Sampling Tool for Urban Environment Land Use/Land Cover (LULC) Indicators: Concept Test in Salvador, Bahia, Brazil

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Abstract

This paper demonstrates the development of an application for consulting and extracting time series of LULC indicators based on Landsat images (built area, vegetation, and surface temperature) with an interactive area design tool, based on JavaScript and implemented in Google Earth Engine (GEE). As a test of concept, the municipality of Salvador was used as a case study and the specific intra-urban region of Parque das Dunas (Dunas Park) is analyzed with data extracted by the tool. The results demonstrate that the interactive temporal sampling translates into a quick tool for assessing changes in the urban environment and the case study points out how the tool and the data can bring answers and generate results quickly.

Keywords: urban environment, remote sensing, GEE, LULC

1 INTRODUCTION

Cities can be analyzed as a system of systems (BATTY, 2009). A common approach to understanding the relationships between urban local systems, such as rivers, vegetation cover and local climate is often the use of land use/land cover (LULC) data because changes in the physical characteristics of the constituent elements of the urban fabric, as well as changes in the forms and spatial arrangements of these elements, directly affect the exchange of matter and energy between the systems, altering their behavior and its consequences can be measured (CUI & SHI, 2012). The urban climate behavior is a good example. The Surface Energy Budget (SEB), which considers the sensible heat exchanges by convection with the atmosphere and by surface conduction and latent heat exchanges by vertical conduction, is highly affected in urban areas. This urban effect is basically attributed to changes in surface cover.

Observing the changes in LULC values over time is essential for capturing significant variations to be recorded and trends to be detected. In the case of urban climate, for example, changes can only be observed and characterized as changes in climate if the observations cover a long period, such as 30 years. But this large amount of multidimensional data, covering big geographic areas and time series, comes with a problem: increasing processing power is needed. Nowadays cloud and parallel computing can effectively address this problem. Cloud computing is seen as a model for enabling ubiquitous, convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released with minimal management effort or service provider interaction. Google Earth Engine (GEE) is an example of cloud computing services available for earth observation (EO) data (LIU et al. 2018; HUANG et al. 2017; CHAKRABORTY & LEE 2019; RAVANELLI et al. 2018)

As a proxy this paper demonstrates the implementation of a interactive tool to choose areas, plot data and export results data for three indicators: 1) proportion of area occupied by vegetation, 2) proportion of area occupied by substrate (built areas and exposed soil) and surface temperature using JavaScript in the GEE code console in Landsat Images from 1984 to 2019. The concept test was applied the city of Salvador de Bahia, Brazil and the Dunas Park area was used to test the intra urban hypothesis that the replacement of the dunes by built up area increased local temperature between 1984 and 2019, possibly affecting the local climate (GRIMMOND, 2007).

2 MATERIAL AND METHODS

The development of the application is based on three modules (Figure 1):

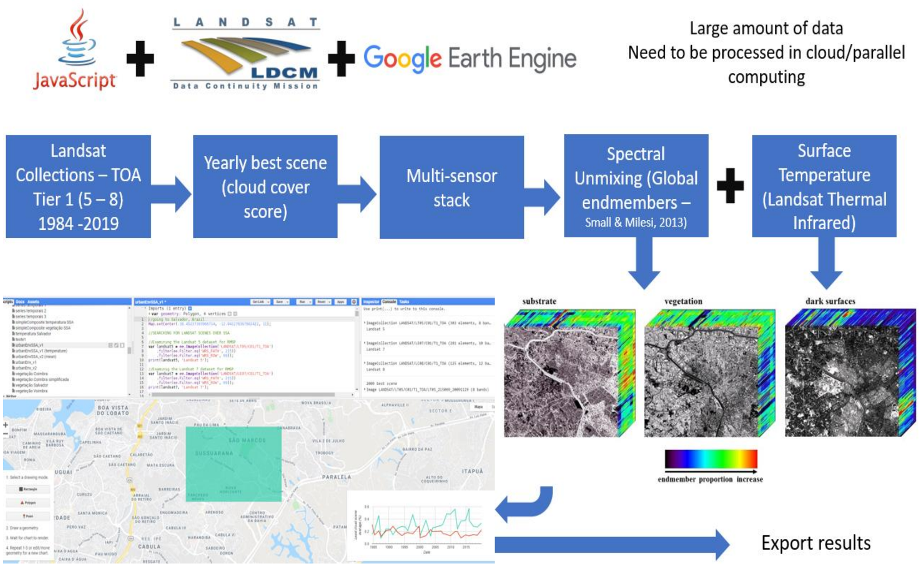

Figure 1: Materials and technical procedures

1) The access and space-time filtering of the Landsat 5, 7 and 8 collections between 1984 and 2019, on which a location filter was applied by Path/Row and the selection of the best annual scene with the lowest cloud coverage per pixel (cloud score). The result generated a new collection of images with 35 scenes; **2)** The calculation of proportional built-up area (substrate) and proportional vegetation, indicators used the spectral unmixing algorithm, applying the global reference endmembers proposed by Small & Milesi, 2013. The surface temperature values were calculated using the thermal infrared bands of the Landsat series with the application of the inverse of the Planck equation, converting its results to Celsius; **3)** The last step was the development and implementation of a user interface based on the selection of areas by three different geometries: points, rectangular areas, or free polygons. A menu of options allows the selection of the geometry and after its manual drawing a graph plotting the zonal mean of the time series for the described variables is automatically generated. It is possible to export the chart and raw tabular data for later use.

3 CONCEPT TESTING: USING THE DATA IN SALVADOR DE BAHIA

The city of Salvador (Figure 2) has about 303 km² of area including tree islands, and is located at 12°47'19", 13°01'06" South latitude and 38°11'51", 38°33'53" West longitude of Greenwich.

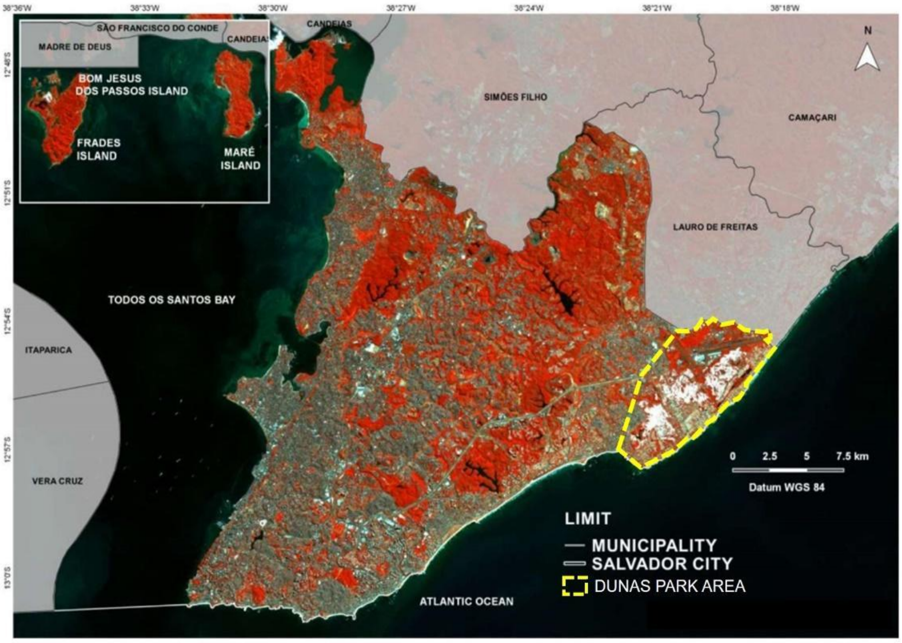

Figure 2. Salvador city and the Dunas Park. Source: Sentinel 2, 2016. Adapted from Santos et al. 2019

The coastal peninsular configuration of the city is influenced by the extensive surrounding water mass, demarcated to three edges which correspond to a bay called Baia de Todos os Santos at West and by the Atlantic Ocean at South and Northwest.

Among the environmentally protected areas of the city of Salvador, the Parque das Dunas, located next to the city's international airport, becomes an area for evaluating the data collection proposed in this interesting work, as it has been undergoing major changes in use and soil storage in its surroundings, with great loss of area of dunes.

4 RESULTS AND DISCUSSION

Having the dune park and its surroundings as a test area, an interesting question stands out: did the replacement of the dune cover by built urban areas over time imply a tendency to increase the surface temperature in this area? This question is interesting because of the characteristics of the materials in question, as well as the impact of urbanization on energy exchanges in the local climate system. To test this hypothesis, the data collected by the developed sampling tool were used. The data processing includes calculating the linear trend coefficients of each of the three indicators, calculating the aggregate moving average every ten years in all data and estimating the trend on the moving average curve. The Figures 3, 4 and 5 present the trend analysis.

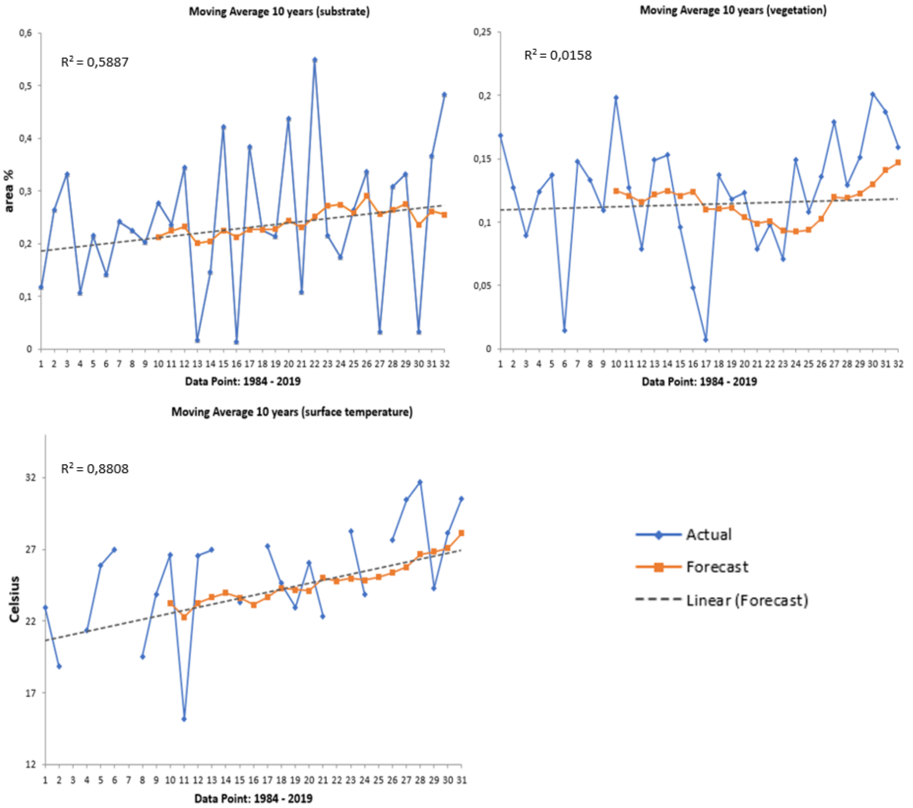

Figure 3 (Built-up/substrate, 4 (Vegetation) and 5 (Surface temperature) trends in the Dunas Park surroundings

The trends show that there is an increase in the area built between 1984 and 2019 in the area, however the proportion of vegetation remains with little change, only variability that can be associated with interannual seasonality. However, the surface temperature shows a high slope in the trend line with an estimated average increase of 3 degrees Celsius in the same period of analysis.

There is evidence that this increase in temperature and its upward trend is associated with soil waterproofing by urbanization, as demonstrated by the Pearson correlation coefficients estimated between the moving average curves of -0.29 between the substrate and vegetation, 0.34 between vegetation and temperature and 0.65 between substrate and temperature. Considering the size of the time series and the amplitude of the average temperature increase, it is possible to speculate about possible local climatic changes associated with the effect of urbanization in the study area.

References

Batty, M., 2009, Cities as Complex Systems: Scaling, Interaction, Networks, Dynamics and Urban Morphologies. *Encyclopedia of Complexity and Systems Science*, pp. 1041–1071. doi:10.1007/978-0-387-30440-3_69

Chakraborty, T. and Lee, X., 2019, A simplified urban-extent algorithm to characterize surface urban heat islands on a global scale and examine vegetation control on their spatiotemporal variability. International *Journal of Applied Earth Observation and Geoinformation*, 74, 269–280. doi:10.1016/j.jag.2018.09.015

Cui, L. and Shi, J., 2012, Urbanization and its environmental effects in Shanghai, China. *Urban Climate*, 2, 1–15. doi:10.1016/j.uclim.2012.10.008.

Grimmond, S., 2007, Urbanization and global environmental change: local effects of urban warming. *The Geographical Journal*, 173(1), 83–88. doi:10.1111/j.1475-4959.2007.232_3.x

Huang, H., Chen, Y., Clinton, N., Wang, J., Wang, X., Liu, C. and Zhu, Z., 2017, Mapping major land cover dynamics in Beijing using all Landsat images in Google Earth Engine. *Remote Sensing of Environment*, 202, 166–176. doi:10.1016/j.rse.2017.02.021

INMET (2016). Base dados Meteorológicos para Ensino e Pesquisa - BDMEP. Instituto Nacional de Meteorologia, INMET. Avalible in: http://www.inmet.gov.br/projetos/rede/pesquisa/ [Acessed 25 Oct. 2016].

Liu, X., Hu, G., Chen, Y., Li, X., Xu, X., Li, S. and Wang, S., 2018, High-resolution multi-temporal mapping of global urban land using Landsat images based on the Google Earth Engine Platform. *Remote Sensing of Environment*, 209, 227–239. doi:10.1016/j.rse.2018.02.055

Ravanelli, R., Nascetti, A., Cirigliano, R., Di Rico, C., Leuzzi, G., Monti, P. and Crespi, M., 2018, Monitoring the Impact of Land Cover Change on Surface Urban Heat Island through Google Earth Engine: Proposal of a Global Methodology, First Applications and Problems. *Remote Sensing*, 10(9), 1488. doi:10.3390/rs10091488

Santos, R., Andrade, T., Branco, N., Borja P., Pedrassoli, J. and Vale, T. Vegetation Cover and Surface Temperature in Urban Areas: An Analysis Using Remote Sensing in the City of Salvador, Bahia, Brazil. Available from: https://www.researchgate.net/publication/318211745_Vegetation_Cover_and_Surface_Temperature_in_Urban_Areas_An_Analysis_Using_Remote_Sensing_in_the_City_of_Salvador_Bahia_Brazil

Small, C. and Milesi, C., 2013 - Multi-scale standardized spectral mixture models. Remote Sensing of Environment 136, pp.442–45