Is there a green roof against urban heat island in Geneva?

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Introduction

During the last century, huge movements of people have been observed between rural and urban habitats. Currently, about 50% of the world population lives in urban areas [4]. With the increase of people in cities, the so-called urban heat island (UHI) effect has become a bigger and bigger problem for health and comfort. Indeed, urban materials like asphalt and concrete trap heat fluxes inside the urban centres. [2] This effect increase locally the temperature, which may lead to several hazards, particularly during summer [1]. A huge amount of studies has tried to describe the role of green roofs as a solution against the heat effect (e.g. Takebayashi & Moriyama, 2007[5], Kleererkorper et al, 2012[3], Zinzi & Agnoli, 2012[7], Susca et al, 2011[6]). Among others, Takebayashi & Moriyama proved by measuring experimental data that the heat flux on green (vegetalized) surfaces would be significantly smaller than on a grey one [5]. Vegetation may then have a reducing effect on heat increase. Susca et al (2011) studied the effect of vegetation and green roofs against UHI in the city of New-York, USA, and used some monitoring stations spread in the city to obtain measures during a complete year. They demonstrated the advantages of having green roofs against UHI, but also for biodiversity and air quality improvement [6]. In this paper, we will focus on the city of Geneva, Switzerland. We will try to measure a reduction of heat measurement in the locations where a green surface is present, and confirm the propositions made previously.

Data

For that study, we used the data coming from two different sources. The thermal data are extracted from the Landsat database (26/06/2018), with the *Earth Explorer* platform[2] [8]. These images are acquired with the B11 Landsat band at 100 metres resolution, and then resampled to 30 metres. We also used data coming from the SITG (*Système d'information du territoire de Genève*)[3]. The green roofs of Geneva are presented in a vectorial form [8], regularly updated (2018) with a precision of 30 cm. Finally, the delimitation of the quarters of Geneva [8] can be found on the SITG website in a vectorial form also.

Methods

QGIS[4] is a free and open-data software, which permits among others things "to create, to edit, to visualise or to publish information of different georeferenced layers"[4]. We used the function "Clip" to trim the thermic layer and the green roof data, in order to correspond to the city of Geneva. Indeed, we neglected the thermic data for the whole Canton (which is composed of rural areas in some parts). After reading the literature[3][5][7], we considered that the effect would be more visible in a real urban environment. Indeed, a first reason is concerning the density of green roofs, which is higher in the urban centre than in the

neighbourhoods, and a second reason concerns the fact that it is better to avoid rural areas, in order to have a more homogeneous city-like domain of study. After creation of a vector grid with a resolution of 20 metres and corresponding to the size of the city, we assigned for each grid cell a thermal value and a Boolean variable for green roof presence with the attribute table of QGIS and the function "Join attributes by location". A green roof would give to the local grid case a "1" value, while no green roof would give a "0" value. The data of the grid have then been used in the Geoda[5] software, which allows to easily describe patterns with different attributes (here: thermal response and green roof presence). We used different sorts of representations for our results, which are briefly described in the next section and explained and shown in figures 1&2 at the end.

Results

The first figure represents a map of Geneva with in a) the corresponding green roofs drawn in green and in b) the thermal response obtained with Landsat 8 measurements. The city is divided into eight quarters. Some parts of the city have more vegetalized roofs in number and area than others, but in a general way the roofs are spread. The thermal map, in b), is a division into five equal intervals of the mean thermal response. If one looks closely to the image, one will be able to observe the grid resolution as a background. The reddish colour is representing a higher value, and a red-white colour corresponds to a lower value.

In the second figure, a series of graphs are represented. The equal intervals from the figure 1b) are used to separate the data to compare them. These graphs are called "Parallel Coordinate Plot" in Geoda and they permit to graphically show the influence of green roofs on the mean heat. In the four first graphs, no difference of intercepted mean range is detectable. However, in the fifth graph, one can observe a slightly difference and the values coming from the non-green roof area seem to have some higher values.

Discussion

The results obtained in the previous part are not very glaring. First, we can observe that 176 thermal values without green roof are higher than the maximum of a green roof case. However, we have to be careful, because more data without green roofs have been observed. If we consider that the global repartition of thermal value is a random variable, it can explain this higher range. To go deeper in detail, we need to take attention to the figure 2. We can observe that, for the four first figures, no real distinction can be made between green roofs and thermal response for small thermal values. It may significate that:

1) The response is not visible (zero hypothesis);

2) The thermal resolution is too rough;

3) The grid resolution (20m) is too rough;

4) The response is only visible for high values; otherwise they are too diluted with other parameters.

From the author's point of view, the fourth option is the more relevant. As previously said, if we look at the last subgraph of figure 2, we can observe a certain tendency of values to be smaller with the presence of a green roof than without. A supposition that can be made is that green roofs have an impact of the thermal response in Geneva, and then potentially on a potential urban heat island but the impact is only measurable when the reflectance effect is noticeable enough.

In summary, the results seem valid, and express the idea that green roofs have a significant effect against UHI. To control or improve this supposition, it would be necessary to test a higher number of green roofs, in

a more dense city, with higher buildings and higher temperature values (more UHI effect)[5]. Increasing the resolution of the thermal layer and the grid may also be a good thing, but it should not change the general conclusions (at least, for Geneva).

Conclusion

As urban heat island are an increasing problem, we tried to observe in this paper the effect of green roof as a possibility to decrease the thermal response. The results shown an impact on high temperatures, but no significant impact on lower. For the particular case of Geneva, it was then complicated to express a true trend. Nevertheless, as Susca et al suggested, the green roofs are not only useful to decrease thermal response, but also as a possibility to increase multiple aspects of health and comfort[6].

References

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[3]URL : https://ge.ch/sitg/

[4]URL : https://www.qgis.org/fr/site/

[5]URL : https://geodacenter.github.io/

Annexes

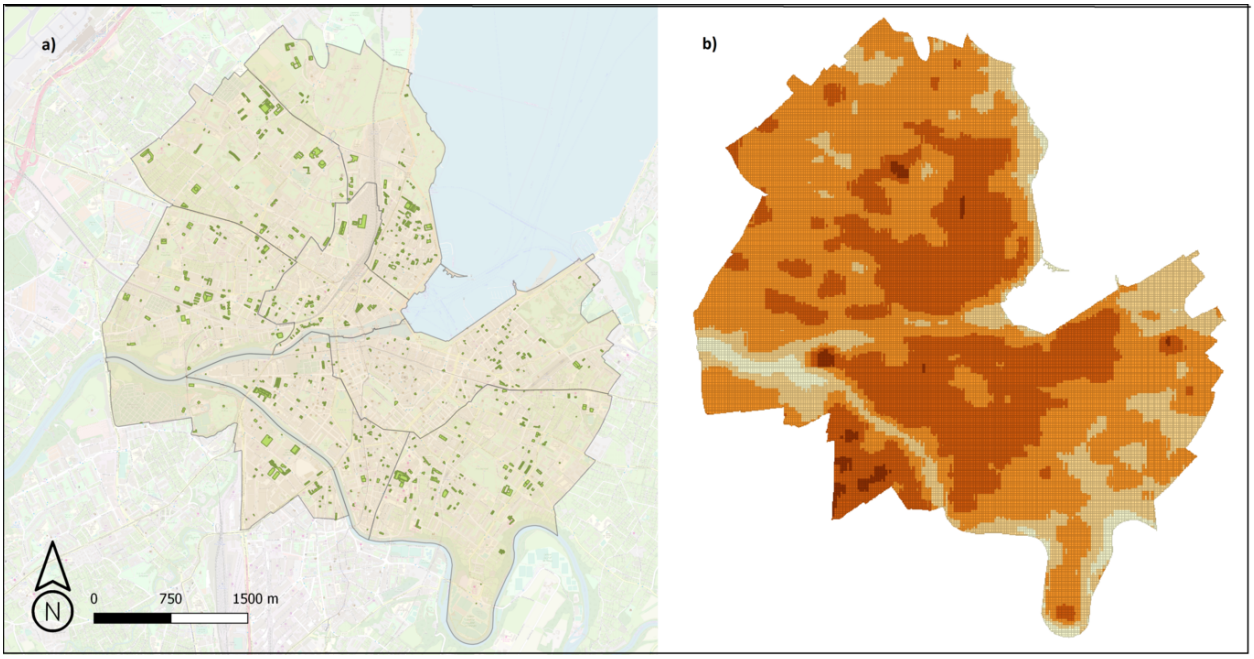

Figure 1: Representation of the city of Geneva with in a) the eight quarters of the city and the green roofs distribution/area and in b) the thermal responses classified in five equal intervals. The high values are coloured in reddish, the low in off-white.

Figure 2: Parallel Coordinate Plot between green roof presences (top–right corner) or non-presence (top-left corner) related to the mean of the thermal response (bottom, increasing values when going to the right). The five graphs represent each an equal interval of the thermal values represented in figure 1b). The first (left) figure represent the lowest fifth of the values, and the last (right) figure the fifth with the highest values.