IOP Conf. Series: Materials Science and Engineering **415** (2018) 012053 doi:10.1088/1757-899X/415/1/012053

GIS modeling of green roofs allocation potential – case study (Kosice)

Z Poorova[1*], Z Vranayova[2]

[1,2] Faculty of Civil Engineering, Technical University of Kosice, Vysokoskolska 4, Kosice 040 01

*zuzana.poorova@tuke.sk

Abstract. Green infrastructure needs to be where people live and work – everywhere in the city. Current city challenges such as hot, dry, pollution, traffic, housing, urban sprawl etc. can be solved simply with nature. Improving stormwater management, changing microclimate, windbreaks, reducing energy use, biodiversity, applying green roof are few examples of solving problems in the cities these days. Ecosystem services must come to towns and people need to learn to use them. Sponge city is not only new term. It provides ecological, economic and social benefit through natural solutions. It is a key to sustainable spatial planning, urban design and development. The aim of this paper is to explain a case study of Košice city how green infrastructure can solve climate petrubation.

1. Introduction

The ideal way to measure any city´s heat island effect would be to examine regional weather patterns with and without the city in the place. Measuring heat island´s effects on regional climate is useful, but it cannot tell how effective mitigation measures would be at reducing a heat island´s effect. This is where modeling becomes necessary. Models are used to predict how well mitigation measures can reduce urban temperatures, energy use, and air pollution and retain water [1].

The simplest and the most common way to analyze a heat island is to compare existing weather data from two or more fixed locations. Fixed station data are used in three different ways:

- comparing data from a single pair of urban and rural weather stations;
- studying data from multiple stations to find regional, two-dimensional impacts;
- investigating a large set of historical data to evaluate heat island trends over time as region was developing.

More rigorous analysis of a heat island includes data from numerous fixed stations in and around the city. If enough stations are available, two-dimensional contour map of the city´s temperatures can be generated [1]. Aim of this article is to show that using available data creating of map of heat island of any city is possible using two main parameters – minimum humidity and maximum temperature.

2. Methodology

According to five year period analysis, World Meteorological Organization (WMO) stated that between 2011 and 2015 was the warmest five year period in the history of observations [2].During this period there have been many cases of extreme weather, particularly heat waves. Situation of the global climate was historic for many reasons. The level of greenhouse gases in the atmosphere has reached new highs in the northern hemisphere during spring 2015 [3]. For the first time it exceeded 3 month average of global concentrations of CO_2. 2015 was the warmest year in the history records in terms of the surface temperature of the oceans since the beginning of observations [4].

In 2016 there were 2-7 more days of summer than in extremely warm year 2015. On the other hand, significantly fewer tropical days were experienced than in the previous year 2015, approximately 15 to 30 days less [5,6].

Summer of 2016 was in all the main features quite different than the summer of 2015. While the year 2015 was extremely warm at the same time it was also very dry. Summer 2016 was much wetter than summer 2015. This resulted in a high number of days and nights, when people feel stuffy. It also resulted in intense thunderstorms. An essential feature of summer 2016 was also part of the transition significant cold front, which also initiated significant convective systems that brought abundant rainfall. That is why in 2016 we did not observe similar long periods of high daily maximum air temperatures exceeding 35 °C as in summer 2015. Characteristic features of the summer 2016 were extremely high temperatures and high frequency of intense storms and torrential rainfalls that are associated with them [5,6].

Following above mentioned information, data from July 01-31, 2015 [7] were used to create map of heat island of Košice city and map of green roofs of Košice city - map of a sponge city using green infrastructure [8]. The concept of a water-sensitive built environment is already established in many urban areas around the world on various scales through approaches such as sustainable drainage systems and low impact development. The traditional idea of managing surface water runoff in an urban environment is to funnel that water away from cities as fast as possible. Recently, however, city planners and governments are realizing that this design concept is flawed as it means that they are, to all intents and purposes, throwing away a highly valuable resource: water. The new mode of thinking is to design a city in such a way that it retains all the surface water runoff that occurs within the confines of the city and that it can be reused at a later date, thereby creating an urban environment that absorbs the water then releases that water when required, in a similar manner to a sponge [9].

3. Results

The mitigation effect of the green roof on urban heat island therefore retaining water in the original area of rainfall therefore lowering temperature and raising humidity is accessible using meteorological measurements. The measurements were collected using automatic weather stations that are installed on roofs of the buildings in Košice.

This research, completing Košice heat island map and map of green roofs of Košice uses only weather stations listed in Tab.1. The study takes into account only parameters given by these stations. For further research of this topic, more parameters will be needed to complete it.

3.1. Data

Table 1. List of max. temperatures and min. humidity

address	max. temperature [°C]	min. humidity [%]
Berlínska 3	**41.1**	**22**
Branisková 25	**36.6**	**25**
Brnenská 41	39.6	21
Bukovecká 43	42.7	20
Bukovecká 68	38.4	22
Cesta pod Hradovou 6	**31.4**	**29**
Čingovská 15	**32.4**	**41**
Čingovská 72	36	25
Magnezitárska 2	**37.8**	**22**
Fatranská 39	37.9	24

Hrabová 8	**43.4**	**19**
Kmeťova 51	35.4	26
Komenského 56	33.8	28
Obrody 63	38.4	22
Park angelium 58	35.1	26
Park mládeže 4	34.2	27
Severné Nábrežie 30	45.1	18
Sokolovská 23	**47.6**	**17**
Starozagorská 5	46.5	18
Šuhajova 49	34.3	27
Šuhajova 70	40.5	21
Turgenevova 66	37	24
Zinková 9	**37.8**	**22**
Zupkova 7	**43**	**19**

3.2. Maximum temperature

The studies on urban heat islands in other cities over the world are focusing on air temperatures rather than focusing on surface temperatures as a first factor. There are several types of heat islands depending on the climate and topography [10].

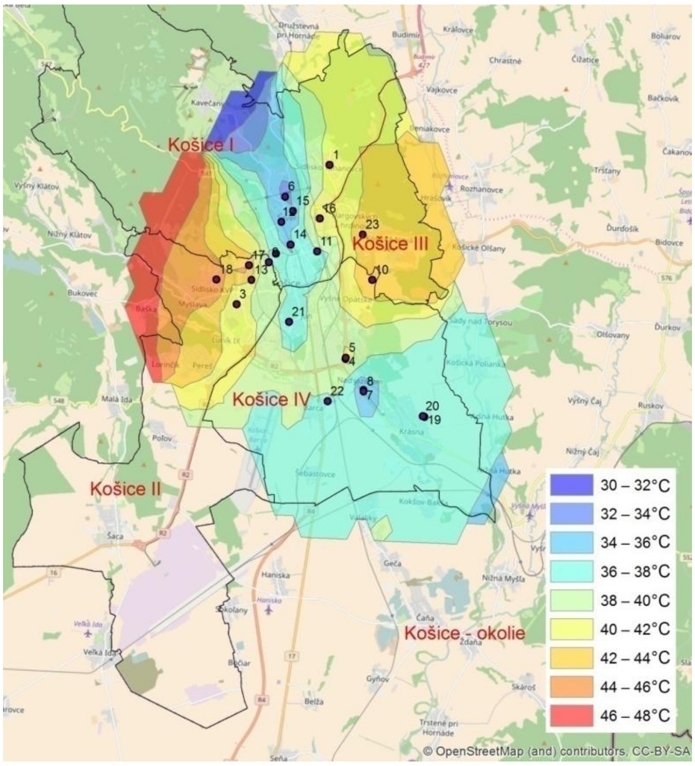

Figure 1. Spatial distribution of temperature trends in July 2015 in Košice (black dots are representing weather stations)

This study of heat island in Košice is focusing also on air temperatures, following study of efficiency of green roofs to mitigate urban heat island effect in Rio de Janeiro [10]. Online data from period July

01-31, 2015 (bold text in Tab.1) were supplemented with calculated data (regular text) caused by gaps in measurement, using data from period July 01-31, 2016, mathematic calculation and taking into account the location of weather station.

The study uses maximum temperatures, because it takes the worst case scenario- extreme into account. Spatial distribution of temperature trends in July 2015 in Košice is shown in Fig.1, detail in Fig. 2. The distribution of temperature trends used only data (max. temperature [°C]) listed in Tab.1. The urban microclimate is influenced by urban form and surfaces. City is characterized by impervious surface with high concentration of anthropogenic activities leading to significant increases in the air temperature and the surface temperature. The urban heat island effect occurs in cities all around the world and it is a result of different thermal properties of surfaces in urban areas. In Košice during summer 2015, up to 15.2°C air temperature differences (minimum 32.4°C, maximum 47.6°C) occurred comparing one housing estate to another housing estate. The biggest extremes are observed in Nad Jazerom and Krásna housing estates. The differences are due to presence of heat station, lake and park near weather stations used for this research.

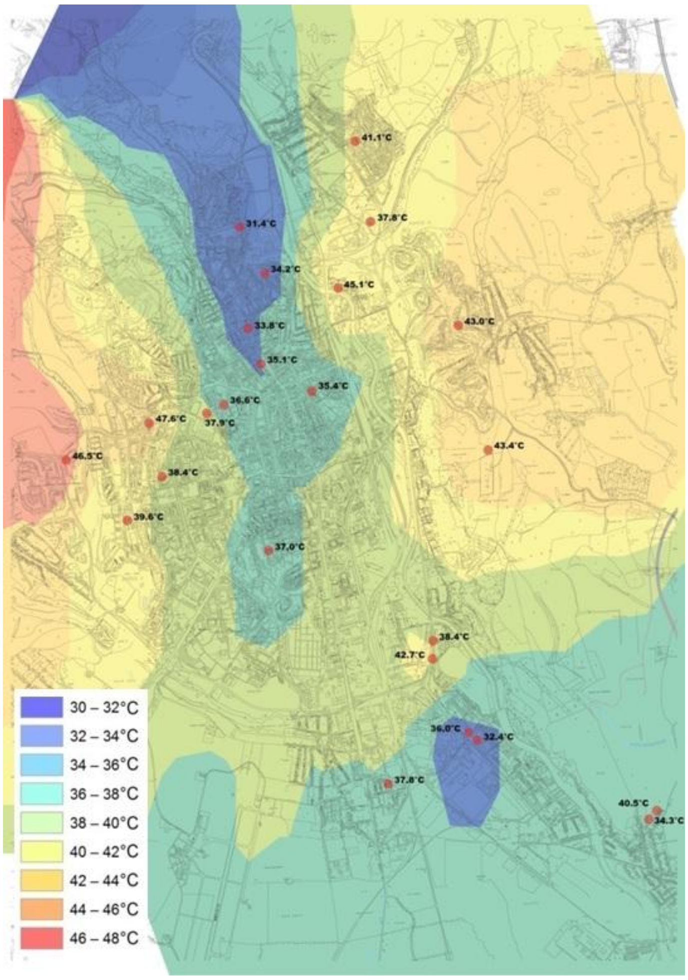

Figure 2. Spatial distribution of temperature trends in July 2015 in Košice

3.3. Minimum humidity

Spatial distribution of humidity trends in July 2015 in Košice is shown in Fig.3. The distribution of humidity trends used only data (min. humidity [%]) listed in Tab.1. The study uses minimum humidity because it takes the worst case scenario - extreme into account. The first radius of minimum humidity of each weather station represents 250 meters, minimal distance between weather stations used for this research. The second radius represents 500 meters.

The detail of spatial distribution of humidity trends in July 2015 in Košice focusing on city centre and surrounding housing estates is shown in Fig.3. The distribution used only data listed in Tab.1. 22 self-governing neighborhoods have more than just one humidity zone. The biggest extremes are observed in Nad Jazerom and Krásna housing estates. These differences are caused because of presence of heat station, lake and park near weather stations used for this research. Important is that these measurement results are related to the temperature measurements. The weather stations with higher temperatures have lower humidity and the weather stations with lower temperatures have higher humidity. In Košice during summer 2015 up to 24% humidity differences (minimum 17%, maximum 41%) occurred in comparison one housing estate to another housing estate.

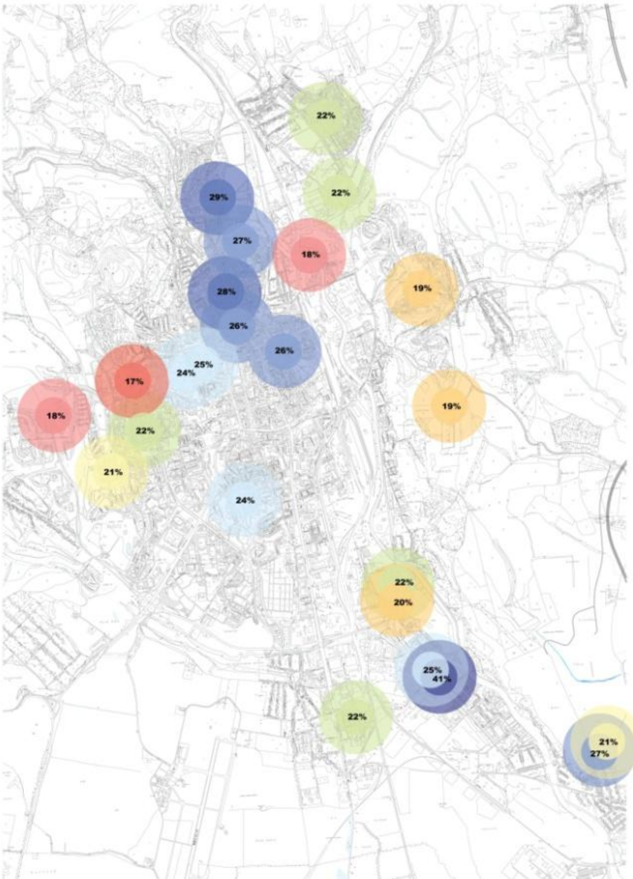

Figure 3. Spatial distribution of temperature trends in July 2015 in Košice - detail

4. Analysis

4.1. Maximum temperature

Modelling and analysing tools of ArcGIS – Geostatistical Analyst – in modelling of spatial distribution of temperature trends were used. Geostatistics is based on the regionalization of random variable in a given area. A set of random variables generated random function. Random function model is based on a study of the spatial variability of the studied phenomenon in different directions – experimental variogram. The result of this study is a mathematical model of variogram defined by changing the spatial variability in different directions of space by anisotropy and autocorrelation. Calculation of empirical semivariogram is written in the form [11]:

$$\gamma(h) = \frac{1}{2n(h)} \sum_{i=1}^{n(h)} [z(s_i) - z(s_i + h)]^2 \tag{6.1}$$

where: $\gamma(h)$ is estimated semivariation for the distance h; $n(h)$ is the number of pairs of measured points separated by a distance h; $z(si)$ is a measured value in point (si).

The first step is the calculation of empirical semivariogram. Followed by the transfer of empirical semivariogram by its theoretical model and determining its parameters. Model found for a given set of data depends on the experimental and theoretical assumptions.

The determining of semivariogram parameters is followed by the actual process of estimating the phenomenon of unknown values based on known data – Kriging [11].

The detail of spatial distribution of temperature trends in July 2015 in Košice focusing on city centre and surrounding housing estates is pictured in Fig.2.

4.2. Minimum humidity

The detail of spatial distribution of humidity trends in July 2015 in Košice focusing on city centre and surrounding housing estates is shown in Fig.3.

Figure 4. Allocation of green roofs in Košice following spatial distribution of humidity trends

5. Discussion

Košice was chosen as a study area to demonstrate the possibility to mitigate low humidity and therefore heat island in the city center and housing estates implementing green roofs and designing sponge city. The paper deals with the possibility to use green roof structures to manage stormwater runoff delay, its reduction into the public drainage system and its storage for later reuse.

Green roofs in urban areas are significant due to their capacity of water storage in the layers of the roof. This capacity, retention quality, allows minimizing the effect of extreme rainfall in short period. Retaining water in the layers of the green roof means reducing the flood peak in the urban drainage system and reducing the risk of water distress.

6. Conclusion

The area with low humidity (17-22%) needs green roof construction with higher retention qualities (Fig. 4, "dots in blue color"). The city area with higher humidity (24-41%) needs green roof construction with lower retention qualities ("dots in green color").

The first radius of suggested green roof construction represents 250 meters. The radius represents minimal distance between weather stations used for this research. The second radius of suggested green roof construction represents 500 meters.

The map of green roofs in Košice (Fig. 4) is modeled using data in Tab. 1. Allocation of two different major types "green color roofs" and "blue color roofs" of green roofs follows these data. More input data is needed to complete more precise and more accurate map of green roofs of Košice city.

7. References

[1] Gartland, L. (2011) Heat Islands. Undrestanding and Mitigating Heat in Urban Areas. London, Earthscan

[2] Coffel, E. D., Horton, R. M., Sherbinin, A. (2017) Temperature and humidity based projections of a rapid rise in global heat stress exposure during the 21st century.

[3] Gutro, R. (2015) NASA - What's the Difference Between Weather and Climate? online: https://www.nasa.gov/mission_pages/noaa-n/climate/climate_weather.html Retrieved: June 11, 2018

[4] Bochníček, O., Faško, P., Švec, M. (2016) Rok 2015 - druhý najteplejší v histórii meteorologických meraní v Európe (2015: second warmest in history of meteorological measurements in Europe) http://www.shmu.sk/sk/?page=2049&id=681

[5] Šťastný, P., Faško, P., Pecho, J., Labudová, L., Ivvaňáková, G., Kajaba, P., Turň, M,

[6] Bochníček, O. (2017) Rok 2016: mimoriadne teplý a veľmi bohatý na atmosférické zrážky (Year 2016: extremely warm year with very rich in precipitations)

[7] Climate: average monthly weather in Kosice, Slovakia (2018) online: www.weather-and-climate.com/average-monthly-Rainfall-Temperature-Sunshine,Kosice,Slovakia Retrieved: June 11, 2018

[8] Yeang, K., Spector, A. (2011) Green design. From theory to practice. London: Black dog publishing. ISBN 978 1 907317 12 5

[9] Atmospheric Humidity And Precipitation (2018) online: https://www.britannica.com/science/climate-meteorology/Atmospheric-humidity-and-precipitation Retrieved: June 11, 2018

[10] Siman, C., Pecho, J. (2017) Extrémne úhrny zrážok v závere júla 2016 (Extreme rainfall at the end of July 2016) http://www.shmu.sk/sk/?page=2049&id=736

[11] Konasova, S. (2016) The efficiency of green roofs to mitigate urban heat island effect in Rio de Janeiro Advances and Trends in Engineering Sciences and Technologies II Edited by Mohamad Al Ali and Peter Platko, Taylor & Francis Group, 6000 Broken Sound Parkway NW, Suite 300, Boca Raton, FL 33487-2742 CRC Press 2016 SBN: 978-1-138-03224-8 http://www.crcnetbase.com/doi/abs/10.1201/9781315393827-80

Acknowledgments

This work was supported by project VEGA n. 1/0202/15: Sustainable and Safe Water Management in Buildings of the 3rd Millennium