Greenery in the urban environment as a nature based solution for thermal stress mitigation

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Abstract. The problem of thermal environment in the city and small urban settlement is described and discussed in the paper. The study was performed for two areas differed in the intensity of development, buildings height and greenery in the nearest surrounding. The results of measurements compared and discussed come from two, local meteorological stations located in both environments. The summer temperature history was compared and analysed using daily maximum, minimum and averaged values. For 85% of analysed days the minimum air temperature in the rural zone was lower than in the regular city area.

1 Introduction

Application of any greeneries in the cities is a nature based solution leading to provide an environment that is sustainable, comfortable and resilient to climate change [1]. In this work, the authors synthesized knowledge from assessments of urban green infrastructure carried out in Europe and beyond to evaluate the potential contribution of regulating ecosystem services to reduce among each other the heat stress at the metropolitan, city and site scales. The mitigation of urban heat island phenomenon is one of the greatest environmental challenges for the sustainability of future cities [2]. Especially, during summer the heat island can effect outdoor comfort conditions for people in the daytime [3]. On the other hand taking into account passive cooling techniques of buildings [4] and its energy consumption including the highest differences of external temperature between day and night are also required. Therefore, any solutions stabilizing the thermal stress are required in design of modern, smart cities.

Interest in transferring urban climatic knowledge into urban planning practices, and developing mitigation strategies to adapt to climate change, has been increased in recent years [5]. The use of vegetation and appropriate urban geometry are shown to be very promising in mitigating the adverse effects of a heat island [6], [7]. The correct choice of vegetation type, shape and density to produce a positive thermal effect during both summer and winter, largely depend on the seasonal conditions of the region. Trees modify the microclimate by altering the solar radiation and terrestrial radiation from the ground by

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providing shading [8]. Therefore, the shading effects of trees were identified as the most important in limitation of heat islands. The shaded areas are characterised by lower air temperatures compared to non-shaded areas [9]. In the Mediterranean coastal region of Israel, N–S oriented streets with trees were found to be cooler by 0.64 K than the E–W oriented canyons during the hottest hours of the day (15:00 h) [10]. Street segments in the city of Bangalore with trees had on average lower temperature, humidity and pollution, with afternoon ambient air temperatures lower by as much as 5.6 K on average [11]. In a high-rise residential area in Hong Kong, an increase in the number of trees from 25 to 40% resulted in a 0.5 K reduction in the intensity of daytime heat island [5]. The field study done in Japan [12] showed that by increasing the number of the trees by 20%, the average maximum temperature would decrease by 2.27 K in the hottest hour of a summer day.

The aim of the study presented in the paper is to investigate the effect of vegetation on temperature of the surrounding environment in Central Europe climatic conditions. Two different locations characterised by a different urban density were considered. The high density zone is characterised for the city centre with averaged building height around 25 m. The low density zone can be categorised as a sparse and single family housing (8 m high). For two selected zones the temperature history in summer months of 2017 was analysed and discussed.

2 Case study

Analysis presented in the paper were conducted based on the results registered at two individual weather stations (Figure 1). The first of them is located in the city centre, in a semi-dense urban environment consisting mainly of tenement houses. The average height of the buildings is at the level of 25 m. The nearest surrounding is characterised by the lack of any vegetation and buildings of similar heights. The ground surfaces are covered with concrete or asphalt pavement in a dark grey colour. The distance between buildings limited the possibilities of self-shading. Geographical position of the first weather station, hereafter named “urban”, is N 51°46' and E 19°27'. The second weather station, afterwards named “rural”, is located outside the city centre in the distance of around 20 km in a straight line to the west from the first weather station. Geographical position of the rural weather station is N 51°47' and E 19°08'. The nearest location is characterised by an open, arable area with a lot of vegetation and few low buildings, not higher than 12 m. The non-natural ground covering is rather unique in that terrain. Analysis was performed for temperature measured in both weather stations in June and August of 2017.

Fig. 1. Locations of selected measurement points.

3 Results

The aim of the analysis was to confirm the hypothesis that even under moderate climatic conditions the effect of vegetation and greenery in the nearest surrounding of buildings effects thermal conditions. We suppose that similarly in the case of the hottest climates, the air temperature in a compact urban environment should be higher during specific periods of the day and night. Additionally, the highest effect of temperature difference is expected for the hottest period of the year, summer months – July and August. This period is characterised by the highest averaged and maximum temperature as well as solar radiation. Additionally, the sun operation in July is relatively long in comparison with other months. The temperature variations registered by two meteorological stations, in an urban and a rural environment were analysed and compared. It was observed that temperature registered in the rural environment was lower almost during the whole analysed period of time. The temperature in evening hours is visibly higher in the urban environment. It can be also noticed that temperature in the rural environment drops much faster after the sun sets than in the urban environment. The daily fluctuations of temperature registered by two selected meteorological stations were presented in Figure 2.

Fig. 2. Fluctuations of temperature registered by two meteorological stations.

Statistical analysis of the temperature changes during the whole analysed 2-month period of time was presented in Figure 3. The maximum air temperatures registered in the analysed period was slightly above 35°C. Only 10 days characterized by maximum temperature above 30°C, which means that the analysed summer was not one of the hottest. The minimum registered values during night were relatively low, even below 10°C. It was noticed that daily peak temperatures registered in the two analysed locations are very similar for most of the days (Figure 3a). For approximately half of the days, the temperature measured in the urban environment was higher than in the rural. The highest differences were observed on the level of 5 K, but during most of the analysed days these differences did not exceeded 0.5 K.

On the other hand, differences between registered minimum daily temperatures are visibly higher and for 85% of analysed days the minimum temperature registered in the rural environment were lower than in urban (Figure 3b). Due to that, similar differences can be observed in average daily temperatures calculated for both locations (Figure 3c). It can be summarized that daily temperature fluctuations in the urban environment are attenuated in comparison to the ones registered in the rural environment. Moreover, close surrounding of compact settlement prevents from temperature drop during the night hours.

It should also be noted that presented results of temperature can be locally disturbed. The distance between both locations is around 20 km and in the specific period of time the solar availability, cloudiness and wind conditions can influence the temperature registered by individual sensors. However, the statistical analysis allows to avoid this inconvenience.

Fig. 3. Values of: a) maximum, b) minimum, c) average temperatures registered by two meteorological stations.

4 Conclusions

The comparative analyses of temperature in a low and high density urban environment were done for two months - July and August 2017. Based on the results registered in meteorological stations it can be concluded that analysed period is relatively moderate. The averaged air temperatures vary between 14 and 28°C. It means that expected temperature differences obtained for hotter summer can be relatively higher.

For 85% of analysed days the maximum air temperature in the low urban density zone was lower than in the regular city area. The highest temperature differences were even 5 K, but during most of the analysed days these differences did not exceeded 0.5 K. The highest differences were noticed when minimum temperatures were compared between low and high density districts. These values were registered usually during the night, which can confirm that green area can lead to reduction of cooling energy. Differences for maximum temperatures, registered during the day are much lower as an effect of intense solar radiation.

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