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REVIEW ARTICLE

Urban heat island research of Novi Sad (Serbia): A review

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Abstract

In the second part of the 20th century, urbanization accelerated and reached enormous magnitude, which results more and more people live in urbanized regions. Nowadays, about half of the human population is affected by the burdens of urban environments and furthermore the modified parameters of the urban atmosphere compared to the natural environment.

Novi Sad (45°15'N, 19°50'E) is located in the northern part of Serbia, i.e. on the southern part of the Pannonian Plain and it is the second largest city in the country with a population of about 320,000 in a built-up area of approximately 80 km^2. The geographical area is plain, from 80 to 86 m a.s.l., with a gentle relief, so its climate is free from orographic effects. According to Köppen-Geiger climate classification, this region is categorised as Cfa climate (temperate warm climate with a rather uniform annual distribution of precipitation).

In the last 20 years, a few papers have been published considering urban heat island (UHI) investigations of Novi Sad. The first publication in 1994 is theoretically based and presents all parameters, methods and measurements, which have to be used in order to work on UHI research of Novi Sad. The next studies from 1995 and 2006 analyzed various temperature parameters based on 30–40 year long time series and used rural and urban stations in order to get urban-rural temperature differences. Based on meteorological parameters and the structure of urban area, in 2010 the necessity of defining locations of an urban climate network was showed in order to advance further UHI research. In the last two publications from 2011 a new empirical modeling method, adjusted for cities located on plains, has been used in order to determine locations for representative stations of an urban climate network in Novi Sad.

Key words: urban heat island, meteorological parameters, empirical modeling method, urban station network, Novi Sad, Serbia

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Introduction

In the second half of the twenty century urbanization reached significant level in the world. Because of that, half of the world population is under negative influence of urban environment, such as: pollution, noise, stress as a consequence of life style, modified parameters of urban climate, etc. Not only the large cities but also the smaller ones modify materials, structure, and energy balance of the surface and almost all properties of the urban atmospheric environment compared to the natural surroundings. Thus, owing to the artificial factors, a local climate (urban climate) develops, which means a modification to the pre-urban situation. This climate is a result of the construction of buildings, as well as of the emission of heat, moisture and pollution related to human activities (Unger et al, 2011a).

Up to now, there are a small number of papers regarding to urban heat island (UHI) in Novi Sad (Popov, 1994, 1995; Lazić et al., 2006; Popov and Savić, 2010; Unger et al., 2011a, 2011b). The main objectives of this study is to present the results of all published papers considering UHI investigation of Novi Sad and propose activities in order to develop UHI research in the future.

Study area

Novi Sad is located in the northern part of the Republic of Serbia (Figure 1) and in southeastern part of Pannonian Plain (45° 15'N, 19° 50'E). The area of the city is characterized by plain relief with elevation from 80 to 86 m and its climate is free from orographic effects. The Danube River flows by the southern and southeastern edge of the city urban area. Southern parts of the city urban area (Sremska Kamenica and Petrovaradin) are located on the northern slopes of Fruška Gora Mountain (539 m). In Novi Sad the annual mean air temperature is 11.1°C with an annual range of 22.1°C and the precipitation amount is 615 mm (based on data from 1949 to 2008). According to Köppen-Geiger climate classification, the region around Novi Sad is categorised as Cfa climate (temperate warm climate with a rather uniform annual distribution of precipitation) (Lazić and Pavić, 2003; Kottek et al., 2006).

Novi Sad is the second largest city in the country with a population of about 320 000 in a built-up area of around 80 km². It is characterized by densely built central area and its surroundings with high buildings and little free space between them. In the northern part of the city is an industrial zone. Green areas in the urban area are found near the Danube, in parks and in suburbs (Unger et al., 2011a).

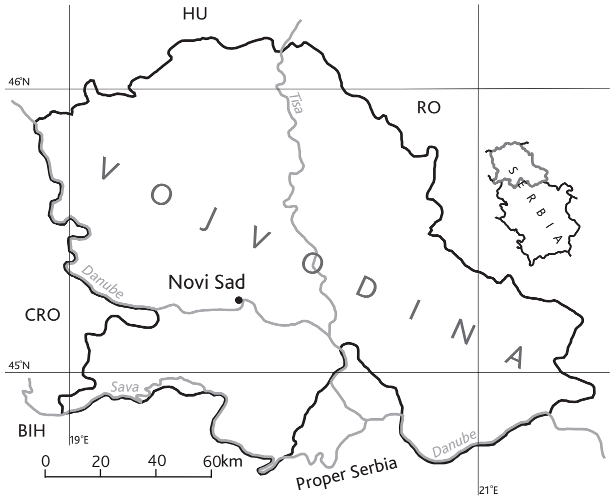

Figure 1. Location of Novi Sad in Vojvodina (Northern Serbia)

Results of UHI investigation in Novi Sad

In the paper of Lazić et al. (2006), the aim was to present a database (mean, maximum and minimum air temperatures, up to 1990) and trends in urban area, using two meteorological stations: one rural (Rimski Šančevi) and one urban (Petrovaradin). As the results showed, there are increasing trends of mean, maximum and minimum temperatures at Petrovaradin, and in most cases these trends are steeper than trends at Rimski Šančevi. Mostly, trends in Petrovaradin are steeper in morning and evening times, in the winter period and annual period. Therefore, the results led to the general conclusion that UHI effect has a substantial contribution on air temperature parameters in urban area around the station Petrovaradin.

Popov (1994, 1995) and Popov and Savić (2010) are the first theoretically based publications, i.e. present all parameters, methods and measurements which have to be used in order to work on UHI research of Novi Sad. At the same time, based on meteorological parameters (for 30-40 years) and the structure of urban area, they showed the necessity of defining locations of an urban climate network in order to advance further UHI research in Novi Sad. They compared temperatures between Petrovaradin and Rimski Šančevi stations and noticed that their differences, at the midday terms, are not important. Furthermore, the anomalies of the temperatures in the summer hardly ever exceed 5ºC. Contrary to this, the number of the morning and evening terms, when temperature anomalies were over 5ºC (sometimes greater than 10ºC), are significant, especially in the late autumn, winter and early spring periods. The general conclusion was that these important urban anomalies of the air temperature always appear in stable, anticyclone situations. According to further UHI research in Novi Sad, they emphasised the necessity of

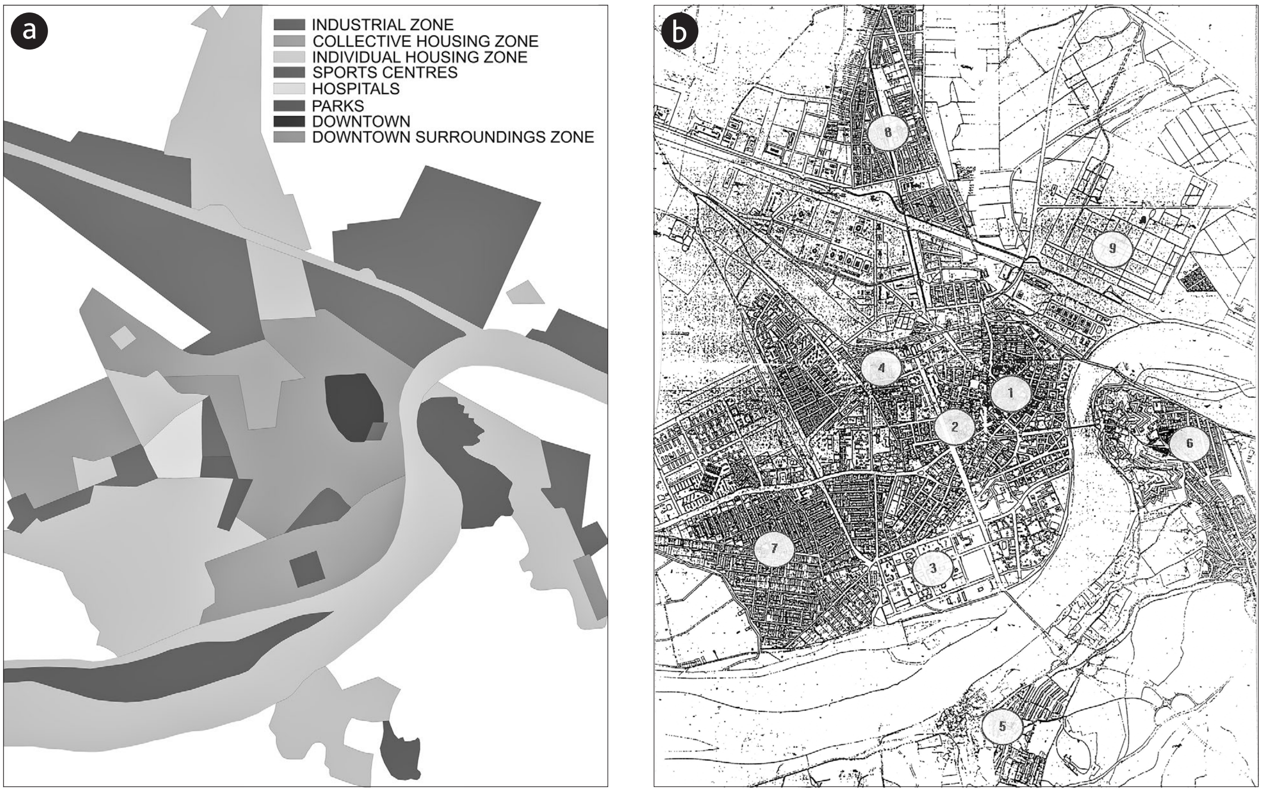

Figure 2. a) Local climate zones and b) proposed urban climate network (Popov and Savić, 2010)

an urban station network. Based on the meteorological parameters from two stations and the defined 8 “local climate zones”, they proposed 9 locations in Novi Sad urban area (Figure 2).

The papers from 2011 (Unger et al., 2011a, 2011b) provided a new contribution in UHI research in Novi Sad. They analysed the spatial distribution of the annual mean urban heat island intensity pattern. This UHI pattern was estimated by an empirical modelling method developed by Balázs et al. (2009), based on datasets from urban areas of Szeged and Debrecen (Hungary). The urban study area in Novi Sad (60 km²) was established as a grid network of 240 cells (0.5km × 0.5km). A Landsat satellite image (from June 2006) was used in order to evaluate Normalized Difference Vegetation Index and built-up ratio by cells. The pattern of the obtained UHI intensity values show concentric-like shapes when drawn as isotherms, mostly increase from the suburbs towards the inner urban areas (Figure 3a). They also proved the accuracy of the model, providing insignificant differences between the UHI intensity value for Petrovaradin cal-

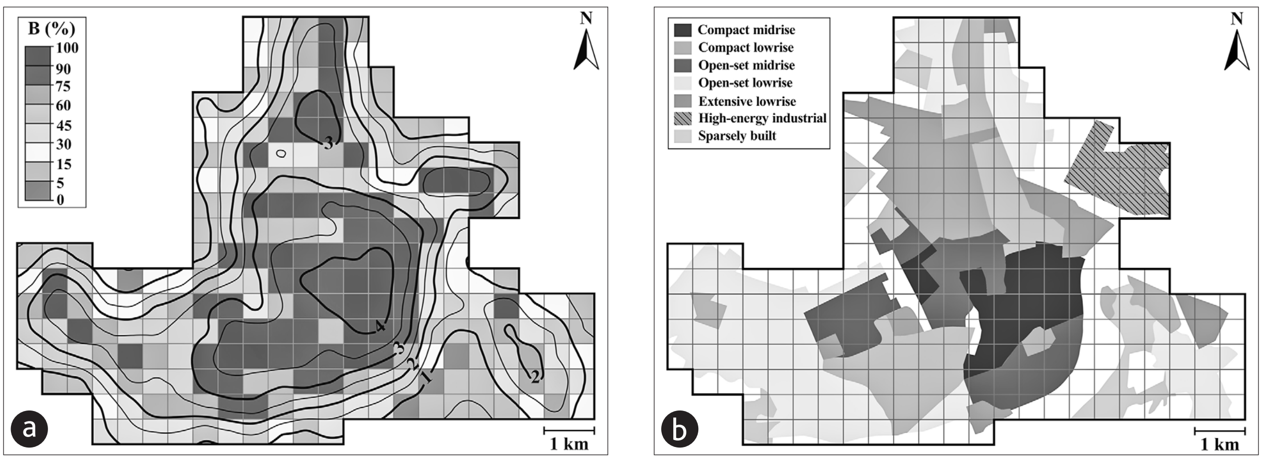

Figure 3. a) Spatial distribution of the built-up ratio (%) and the modelled annual mean UHI intensity (°C) in the study area of Novi Sad (Unger et al., 2011a) and b) spatial distribution of urban Local Climate Zones (based on Stewart and Oke, 2010) occurring in the study area of Novi Sad

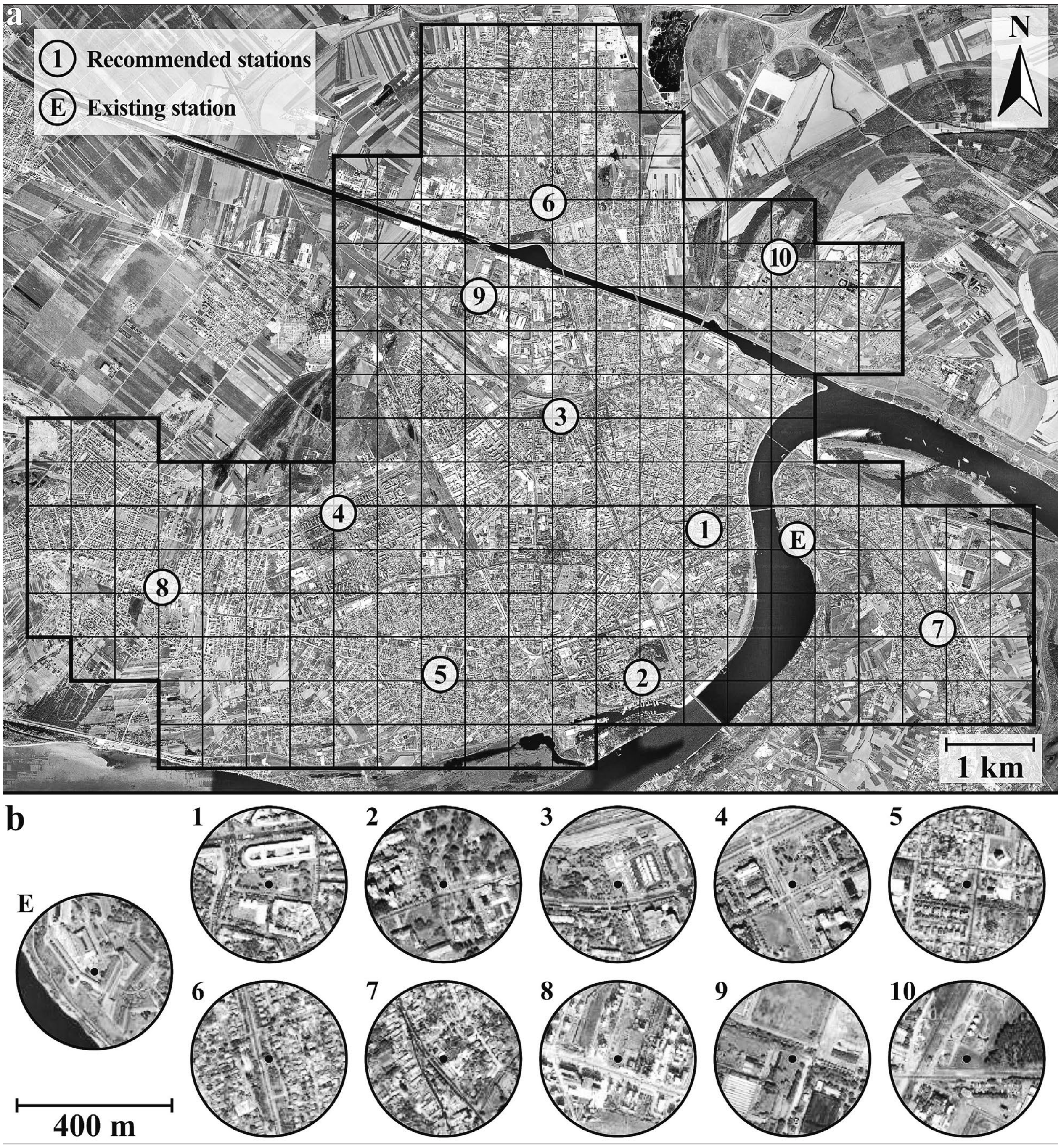

Figure 4. Satellite image of the study area in Novi Sad with the existing stations and the recommended sites of a 10-station urban climate network (Unger et al., 2011a)

culated by the statistical model (1.66°C) and the measured one (1.8°C). Further work was based on the analysis of the thermal pattern and determination of the local climate classification (LCZ) system (Stewart and Oke, 2010) (Figure 3b), in order to determined 10 locations for representative stations of an urban climate network in Novi Sad (Figure 4).

Conclusions

According to the analysis in the reviewed papers, it is revealed that the urban heat island effect exists in Novi Sad area. Therefore, further detail research of UHI pattern and its effect on human thermal comfort needed.

The first step can be done through an IPA HUSRB project made by Department of Climatology and Landscape Ecology (University of Szeged) and Faculty of Sciences (University of Novi Sad). The long-term and effective monitoring of these changes is possible with the application of an installed (wireless) monitoring network, whose spatial resolution provides the detection the differences between thermal characteristics of the neighborhoods, and whose temporal resolution allows the exploration of both the diurnal as well as the seasonal peculiarities.

As Szeged and Novi Sad are located in plan areas devoid the climate modification effects of topography, thus the explored thermal (heat load) differences virtually depend on their built-up characteristics and anthropogenic activities. Therefore, these cities are ideal places to explore clearly the climate – in our case primarily the thermal load – modification effects of the artificial factors and their temporal and spatial differences in greater detail.

Summarizing, such type of monitoring networks in these cities and the associated continuous data recording, transmission and processing, as well as the real-time public display of the processed data in a spatial (map) form would mean a unique and pioneering innovation development in Central Europe. This database would be extremely useful as a test bed for the urban parameterizations of weather and climate forecast models. The long-term operation of the network and the resulting database that contains also the parameters related to weather situations, in the future provides a few days (nowcasting type) forecast of the expected heat load of the spatial differences within the city as well.

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