World Academy of Science, Engineering and Technology
International Journal of Urban and Civil Engineering
Vol:13, No:8, 2019

Demonstration of Land Use Changes Simulation Using Urban Climate Model

Barbara Vojvodikova, Katerina Jupova, Iva Ticha

***Abstract*—**Cities in their historical evolution have always adapted their internal structure to the needs of society (for example protective city walls during classicism era lost their defense function, became unnecessary, were demolished and gave space for new features such as roads, museums or parks). Today it is necessary to modify the internal structure of the city in order to minimize the impact of climate changes on the environment of the population. This article discusses the results of the Urban Climate model owned by VITO, which was carried out as part of a project from the European Union's Horizon grant agreement No 730004 Pan-European Urban Climate Services Climate-Fit city. The use of the model was aimed at changes in land use and land cover in cities related to urban heat islands (UHI). The task of the application was to evaluate possible land use change scenarios in connection with city requirements and ideas. Two pilot areas in the Czech Republic were selected. One is Ostrava and the other Hodonín. The paper provides a demonstration of the application of the model for various possible future development scenarios. It contains an assessment of the suitability or inappropriateness of scenarios of future development depending on the temperature increase. Cities that are preparing to reconstruct the public space are interested in eliminating proposals that would lead to an increase in temperature stress as early as in the assignment phase. If they have evaluation on the unsuitability of some type of design, they can limit it into the proposal phases. Therefore, especially in the application of models on Local level - in 1 m spatial resolution, it was necessary to show which type of proposals would create a significant temperature island in its implementation. Such a type of proposal is considered unsuitable. The model shows that the building itself can create a shady place and thus contribute to the reduction of the UHI. If it sensitively approaches the protection of existing greenery, this new construction may not pose a significant problem. More massive interventions leading to the reduction of existing greenery create a new heat island space.

***Keywords*—**Heat islands, land use, urban climate model.

I. Introduction

URBAN areas which give home to significant proportion of Earth´s population lives are inevitably impacted by global climate changes About 55% of the planet's population lives in urban areas [1]. . In the Czech Republic, this percentage is nearer to 70% [2]. This is a significant proportion of the population. Cities evolve in accordance with the requirements of housing, jobs and transport. This historically based development [3] that changes land use in urban centers, and also on their outskirts, must be analyzed and adapted to current natural conditions in the interest of the population.

Climate changes have started to be recognized in recent decades. As many authors point out, the temperature is rising in the whole of Europe [4] and also in other parts of the world. It is also to be expected that the heat waves that are linked to this trend will continue [5]. Heat waves can then lead to increased mortality [6], and pose a problematic aspect in sustainable urban development. As confirmed by several studies, this trend of temperature rise and the formation of UHIs is more significant in the urbanization process [7].

The increase in average annual temperatures can also be expected in the Czech Republic [8]. Overall climate changes have been addressed in the Czech Republic by developing adaptation strategies to climate changes at state level, and in some municipalities [9]. All of them agree that one of the important elements which can contribute to the deterioration or to improving the condition are land use changes. The change in land use is a significant societal trend. About one-third of the global land surface has already been altered by land use and land cover changes (LUTCC) [10]. Also related to the land use changes and the temperature is the carbon balance [11] and construction industry, where it is necessary to search for cement replacements [12], [13] by more friendly materials in terms of carbon footprint. Description of the relationship between land cover types and climate change was presented by [14]. For the discussion about the wider context of climate change, the application of appropriate models which also visualize some of the problems [15]. Often, the city or neighboring administrations are not able to properly illustrate and evaluate the impact of specific city-planning decisions and strategies on the level of heat stress. Especially, there is a lack of services and tools available for such assessment, based on a decent scientific background that would be user-friendly for city officials and city representatives. Urban planning service Climate-fit city and its application, which is described in this article, is based on the Urban Climate Model [16] owned by VITO. This service should assist cities in finding suitable alternatives to changes in landscape in conjunction with spatial planning and urban planning.

II. Service Description

The urban planning service focuses on the influence of the urban land use structure (changes of land use and land cover) on the level and spatial distribution of the heat stress in urban areas. Through modification of the input land use layer,

B. Vojvodikova is with the IURS - Institute for Sustainable Development of Settlement, Ostrava, 708 00 CZ (phone: +420-732-117-244; e-mail: iurs@ email.cz).

K. Jupova is with GISAT s.r.o, Praha, 170 00 CZ (e-mail: katerina.jupova@ gisat.cz).

I. Ticha is with the Faculty of Social Studies, University of Ostrava, Ostrava,70100 and CZ (e-mail: itichai@seznam.cz).

various city-development scenarios can be simulated and the corresponding distributions of the heat stress levels in the area of interest are modelled/re-calculated. This scenario-modelling service is provided in two different spatial scales:

- City level – in 100 m spatial resolution.
- Local level – in 1 m spatial resolution.

For the city level of modelling, an interactive scenario modelling tool has been developed, enabling the user to interactively model different scenarios of the city development online and then directly run the modification of the resulting map showing distribution of the heat stress levels in the city.

The service brings to the users the unique possibility to follow the influence of the city structure (spatial distribution of different types of urban land cover and land use) on the level and distribution of the heat stress over the city (or in a smaller area of interest inside the city.

Testing of climatic models [17], [18] is usually carried out in metropolitan areas or in the whole regions. For testing of the Urban planning service Climate-fit city, we have deliberately selected smaller towns to verify its use in typical Czech environment. This article is focused on testing in Ostrava and Hodonín.

III. Pilot Territories Description

Ostrava is the third largest city in the Czech Republic. (population of 300 thousand). By the end of the 90s, the urban microclimate was decided by the presence of heavy industry and mines, since this time begins the process of suburbanization that brings significant changes in urban structure. While coal mining has been abandoned, several major industrial companies in the city still remain in operation.

It is a city with a non-compact build-up area; in fact, there are three major residential centers, and the space between them has been filled during the last 15 years by shopping centers. Ostrava lies at the confluence of three major rivers of the Moravian Silesian region. There are few heaps in the structure of the city, most of them already after reclamation. Three of them are burning so they constitute heat islands. Both scenarios have been applied on the area of Ostrava.

Hodonín is a town in South Moravia, on the border with Slovakia and near the border with Austria. It is a historical city with compact build up area. The Slovakian border is formed by the River Morava. Hodonín has an area of 63.05 km^2 and a population of over 25,000 residents. This is a town located in the Dolnomoravsky valley, basically a flat area transitioning into the Pannonian plain. Hodonín is historically connected with the extraction of oil. For Hodonín, the model was applied at the local level - in 1m spatial resolution - based on a request from the municipality and with regard to the scale of the projects the municipality prepares.

IV. Specification of the Case Study

Demonstration of the model application was done according to requests from municipalities.

City-administrations need a scientifically-based justification of anticipated environmental effects in order to enforce the more environmental-friendly urban planning decisions (or city-development scenarios) and to support more sustainable development strategies of their city.

As part of the urban planning, service testing for the local level is 1 m spatial resolution. The problem was tackled in close cooperation with the cities and everything was done in three basic steps.

The first step was for cities to provide a specific problem (a specific location) that it solves within its urban structure. In the second step, in cooperation with VITO, the owner of the Urban Climate Model [16], evaluation of specific problems was prepared. The results were then submitted to the providing city for verification and comment.

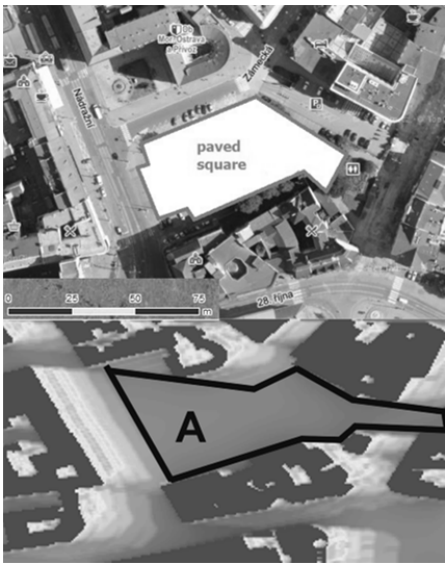

Fig. 1 Ostrava Eduard Benes sq. – first scenario (A -area with a high temperature stress)

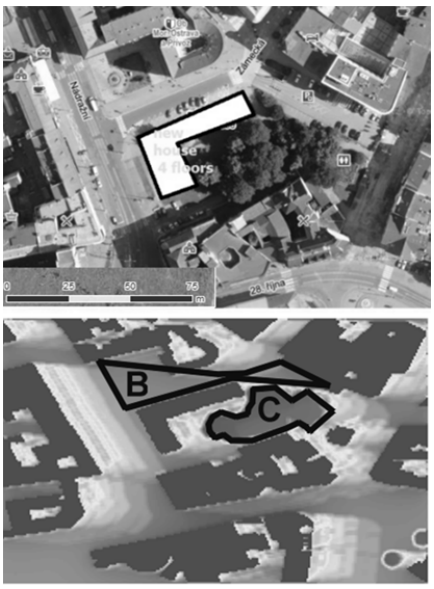

Fig. 2 Ostrava Eduard Benes sq. – second scenario (B - high temperature stress C - low temperature stress)

The problem of Eduard Benes's square - was modeled in 1 m spatial resolution for Ostrava. At present, the city prepares an urbanistic competition for this particular area, and wanted in advance, to prevent the problem of the formation of a heat island by excluding inappropriate variants from the competition.

The city's request included an evaluation for the two most controversial scenarios. The first scenario proposed the liquidation of the current greenery and the pavement of the whole area. Fig. 1 shows area A which has been evaluated as a place with a high temperature stress.

In the second scenario, placement of a new building was considered together with preserving the maximum of the existing green. Fig. 2 shows area B, a place of high temperature stress, and area C, a place with low temperature stress.

Fig. 3 Hodonín - variant without new planting and new green areas. (area identifies a place with low temperature stress)

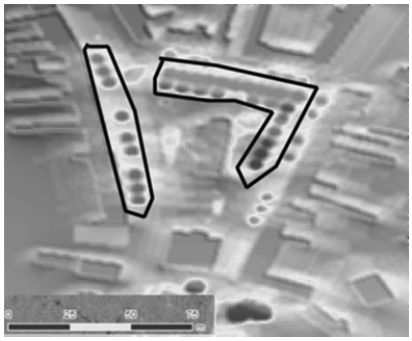

Fig. 4 Hodonín - variant with newly planted trees (area identifies a place with low temperature stress)

Representatives of the city of Ostrava evaluated the results of the model application and found them to provide very useful information for the specification of the urban competition. It was confirmed that paving the whole square will be totally unsuitable due to temperature rise in the surroundings. Conversely, construction of a new building would be possible from the point of view of UHIs.

Hodonín town requested an evaluation of two solution variants for parking areas at Masaryk's Square in Hodonín. This project is under preparation and the final version will have to be approved by the town's council. Fig. 3 shows the evaluation for the variant without new planting and new green areas (area identifies a place with low temperature stress). Fig. 4 shows a variant with newly planted trees and expansion of the green areas (the more expensive option with less support from the town's representatives) and indicates places with low temperature stress.

The representatives of Hodonín evaluated the results of the modeling as interesting and will present them for discussion at the meeting of the town's council. The result illustrates the possibilities of using the urban planning service as an argumentative tool for enforcing the more expensive but more suitable option from the point of view of resident's welfare.

For city level – in 100 m spatial resolution, the web application and its entire functionality has been tested by representatives of municipalities, together with a group of experts. Within the city of Ostrava, the testing evaluated effects of burning heaps and their possible remediation, effects of the regeneration of some brownfields to an industrial zone and to park zones or effect of the construction of a new industrial zone on a greenfield.

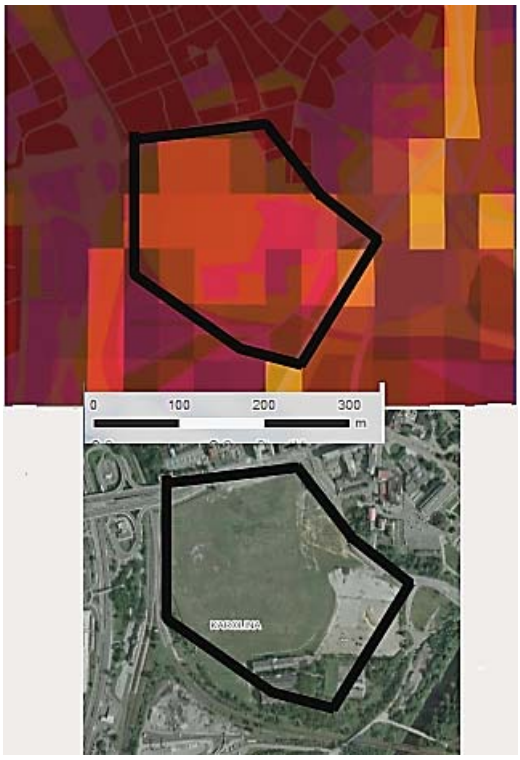

Fig. 5 Karolina site - Green space- model - situation in 2006

The main added value of the Climate-fit city service is the high level of the user-driven interactivity provided by the interactive scenario modelling tool, which has been developed as one of the main features of this sectoral service. This application runs online and is easily accessible to any computer user with internet connection directly from the browser window. Prepared in which user can model temperature changes in relation to changes in land use.

Fig. 5 shows a situation about the temperature distribution of temperature stress in 2006, when the most well-known brownfield Karolina in Ostrava was after remediation works

and served as a green area. Fig. 6 shows the current state of the site with a significant temperature island marked which has been created by building a shopping center with large paved areas.

Fig. 6 Karolina site- after development- situation in 2018

All of these pictures illustrate very well the impact of town planning decisions (urban, strategic) on climate conditions in urbanized areas. It provides a scientifically proven rationale for the aforementioned decisions in urban planning, which then can be more environmentally friendly.

V. Conclusion

Our service is built on the scientifically well-proven and reliable modelling method, which is used by the UrbClim model operated by VITO [16], and therefore represents a very convincing basis for urban climate data production and modelling. UHIs pose a problem mainly in the rise in the number of hot days and tropical nights. [19]. These climatic changes and heat stress pose a threat to public health. [20].

The two different levels of spatial detail which are offered by this service (100 m – city level, 1 m – local level) provide the support for both city-level and sub-city level administrations, for both large and small cities. Also, the strong added value lies in the potential for combination of both these spatial levels of detail, bringing the users a possibility to look at the complex climate conditions of their city and at the same time to look at very specific development areas in the city and their local climate conditions.

Acknowledgment

This article was prepared thanks to support thanks project Pan-European Urban Climate Service - PUCS Grant Agreement Number: 730004, Service Name: Climate-fit.city.

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