Chapter 14
Pilot Actions in European Cities – Prague

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Abstract This chapter describes results of pilot actions in Prague. Two different pilot areas were selected (Legerova street and Bubny-Holesovice quarter) with different modelling approach. Finally, the Green belt around Prague is studied as well. Different scenarios are tested and their results discussed. The matter of air quality is also analysed.

Keywords Urban heat island of Prague • Potential equivalent temperature • Mitigation of urban heat island • Effects

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14.1 Urban and Environmental Framework

14.1.1 General Remarks on Prague

Prague is the capital of the Czech Republic. As the largest city in the country by its area (496 km^2) and by population (1.2 million inhabitans) faces the same environmental challenges, as the other large cities in the world. The city strives for the substantial reduction of the environmental burden as to become clean, healthy, and harmonic place for living. Prague is situated on the banks of the Vltava river and its tributaries. The complicated morphology creates limitation for a good ventilation of the area. The lowest point is in 149 m and the surrounding hills at the southwestern part of Prague are almost 400 m above sea level.

14.1.2 Prague Urban Heat Island Analysis

Prague and especially its city centre belongs to the warmest regions of the Czech Republic with annual average air temperature around 10 °C in the city centre (see Fig. 14.1). This is partly caused by the urban heat island (UHI) of Prague.

The intensity of UHI is about 1.6 °C when we use the average daily temperatures. The highest intensity occurs during June, while the lowest intensity in September. It has to be noted, that the UHI intensity of Prague is considerably higher when looking at minimum temperatures (annual average is approximately 3 °C) but smaller for maximum temperatures (annual average approx. 1 °C). The intensity of Prague's UHI has increased during the last 50 years. This increasing is caused due to the city enlargement and transport intensification.

The magnitude of this intensification is 0.15 °C/10 years for minimum temperatures, 0.07 °C/10 years for average daily temperatures and 0.02 °C/10 years for maximum temperatures. This intensification of UHI is documented on Fig. 14.2 where differences of daily air minimum temperatures between period 2001–2010 and 1961–1970 are demonstrated. While the temperature in the whole Prague area increases (due to the climate change in the Central Europe), the largest increment of the temperature can be seen in city centre, close to the Vltava river, in the densely built up part of the city.

Another point of view of the intensity of UHI can be obtained by using physiological equivalent temperature PET (Matzarakis et al. 2010). This temperature describes the temperature really felt by the human being standing outside and includes not only influence of air temperature and wind, but also humidity and radiation including the radiation coming from buildings in the streets. The average annual and daily course of PET for the Praha–Karlov stations is given in Fig. 14.3. It can be seen, that the highest values occur during summer months, July and the first half of August.

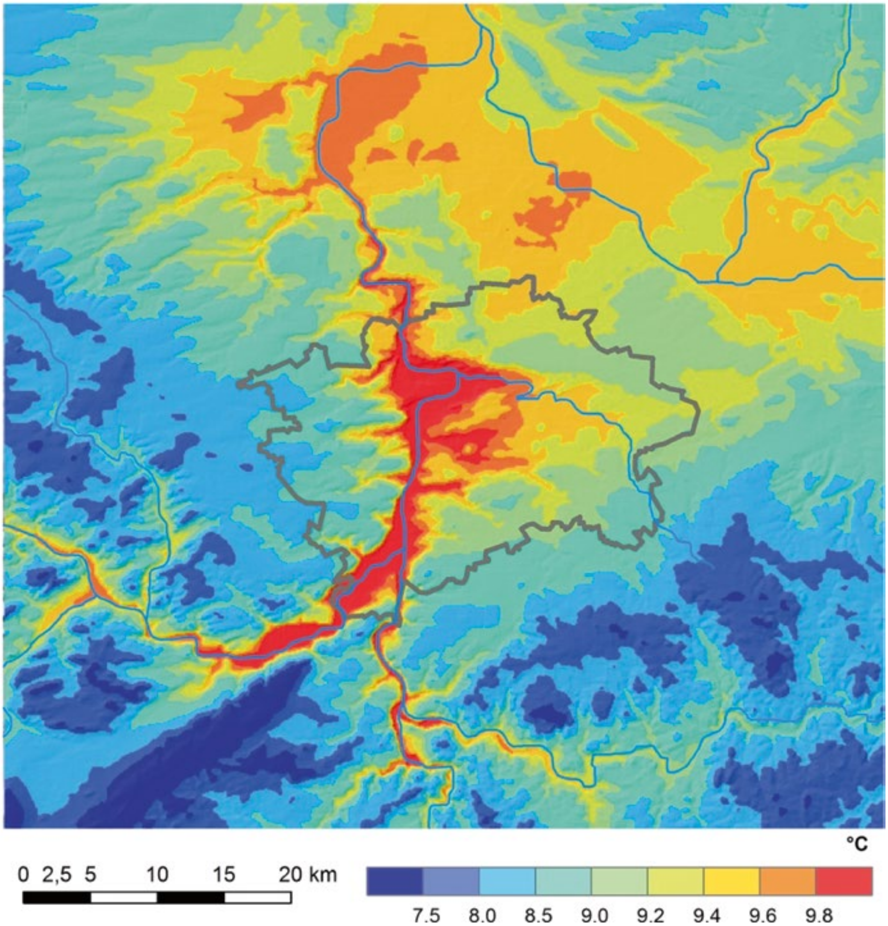

Fig. 14.1 Annual average air temperature for Prague and surrounding, period 1961–2010

The differences of PET values between Praha–Karlov station located in the city centre and Praha–Ruzyně station situated on the periphery of the city (Fig. 14.4) show the highest values in the summer half of the year starting after the sunset and vanishing during the morning hours. Few hours after the sunrise this differences can be even negative indicating lower PET values in the city centre. Regarding long term changes, there is positive trend in PET values in Prague during spring and summer indicating greater human stress during the warm summer half-year. It should be noted that PET was computed for the location with ideal horizon without obstacles – this is also the case of the following case study of a hot day.

The largest UHI negative effects (in the sense of bioclimatic discomfort) usually occur during the summer months. For demonstration, case study of hot day, the day of 28th July 2013 has been chosen. Maximum air temperature on that day reached

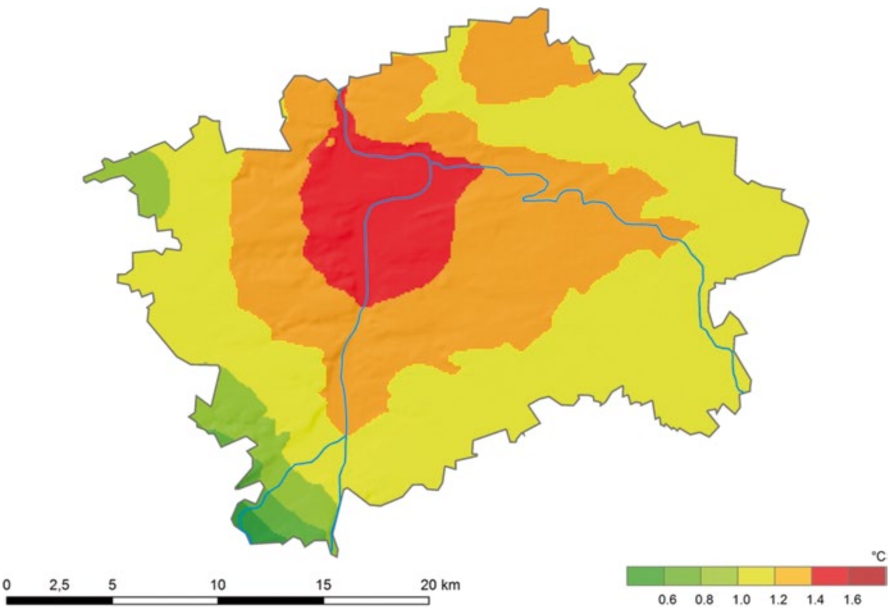

Fig. 14.2 Difference of daily air minimum temperature between period 2001–2010 and 1961–1970

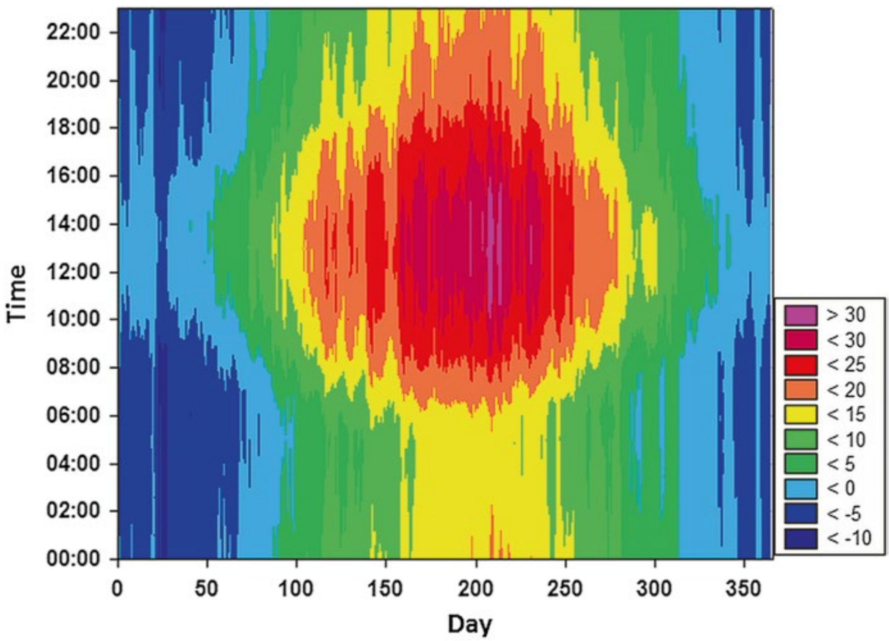

Fig. 14.3 Annual course of PET for Praha-Karlov station, period 2005–2013

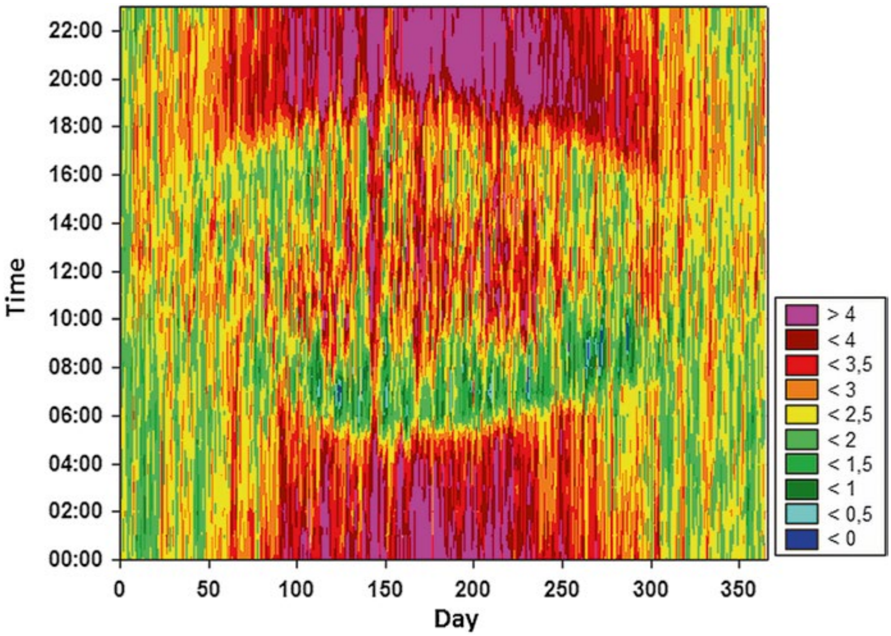

Fig. 14.4 Annual course of PET of differences between stations Praha-Karlov and Praha-Ruzyně, period 2005–2013 (positive values mean Karlov is warmer than Ruzyne)

values around 37 °C (Fig. 14.5), with differences among different parts of the city being maximal about 2 °C. PET values (Fig. 14.6) on that day reached over 46 °C in the city centre, with difference through the city being a bit higher compared to the differences in the air temperatures. Values of PET over 40 °C started already around 9 in the morning and continued to 5 in the afternoon. Especially in the evening, the differences between city centre and periphery exceeded 8 °C.

14.1.3 Air-Quality Issues

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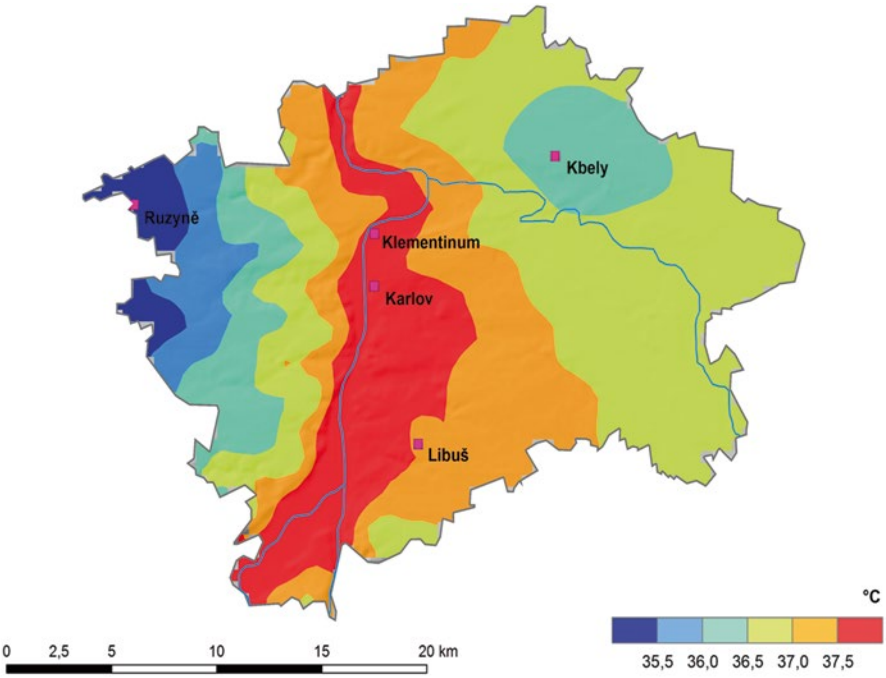

Fig. 14.5 Maximum air temperature in Prague on 28th July 2013

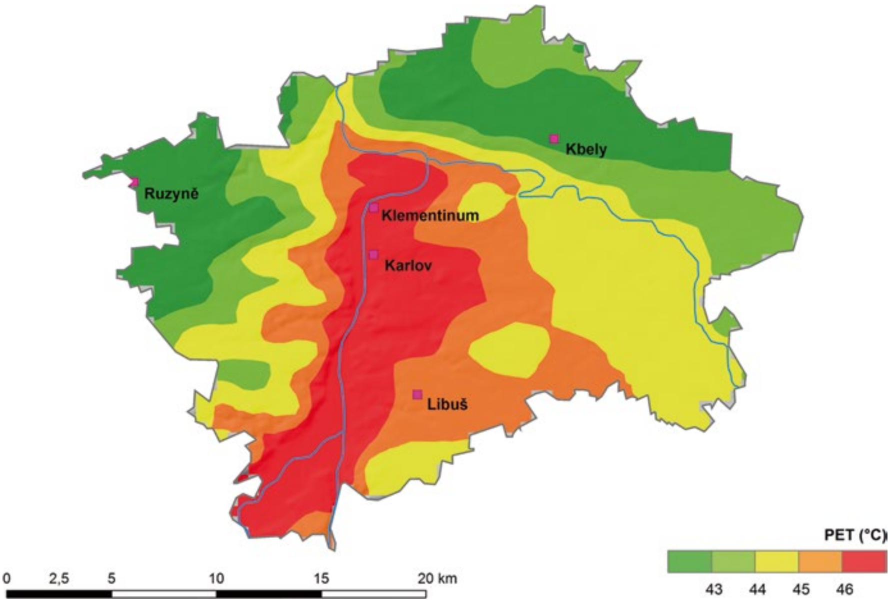

Fig. 14.6 Maximum PET in Prague on 28th July 2013

Despite the substantial reduction of the emissions from industrial sources in the past years, air quality is still influenced by the emissions from automotive traffic, as a main source of air pollution. In the suburban residential areas air quality is influenced by the emissions from local heating burning solid fuels.

In the agglomeration of Prague the limits for air quality are exceeded, especially for particular matter PM10, NO2, O3 and benzo(a)pyren. The majority of exceedances is connected with the high traffic loads in Prague, but also with the domestic heating in family houses in the residential areas in Prague.

The share of mobile sources on the total of PM emissions is more than 85 %, on the total of NO_x ca 75 %. The contribution of the household heating to PM emissions is almost of 16 %.

In the last years the ambient air quality has been improved. The annual limit concentration NO_2 (40 $\mu g.m^{-3}$) has been exceeded only on two traffic monitoring stations in Prague, however it can be supposed that the exceeding could occur in other areas with a similar traffic volume.

Also the PM_{10} concentrations dropped significantly, nevertheless the average 24 h PM_{10} concentrations are exceeding the limit at the 13 monitoring stations.

The concentrations of benzo(a)pyren measured at two monitoring stations in Prague were exceeded only at one of theme, the results of monitoring fluctuates around the limit of 1 $ng.m^{-3}$.

The concentrations of O_3 are regularly exceeded only at the one background station in the suburb over years.

The rest of the air quality limits are usually met in the area of Prague (Figs. 14.7 and 14.8).

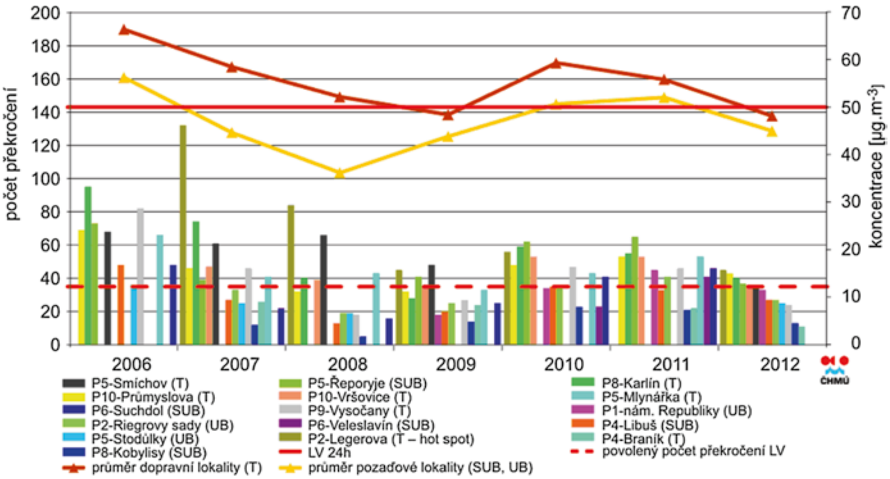

Fig. 14.7 Trends in yearly characteristics of the fraction PM_{10} and the 36th highest 24-h PM_{10} concentration in selected monitoring stations in Prague

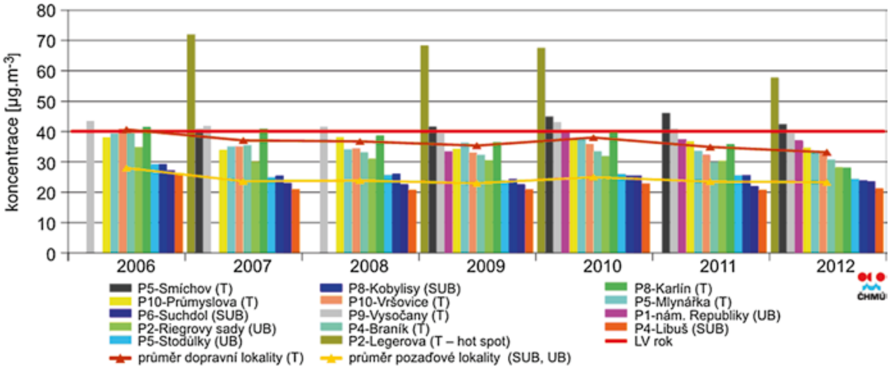

Fig. 14.8 Trends in yearly characteristics of NO_2 in selected monitoring stations in Prague

14.2 Pilot Areas Identification Methodology

The pilot areas in Prague were selected with the aim to enable the simulation of UHI mitigation strategies in different scales.

For the scale of a street canyon the Legerova street was selected, representing one of the streets with a very high traffic volume crossing the residential area.

For the Pilot Area 2 was chosen the brownfield Bubny – Holešovice, an abandoned railway area, which aspires to be a new city quarter. Microclimatic simulations were performed for the central part measuring 500 m by 500 m.

The Pilot Area 3 as the whole territory of Prague has been chosen to enable simulations of the mitigation effects as a green belt around Prague or traffic emission reduction in all Prague agglomeration.

14.3 UHI Phenomena in the Pilot Area and Connection with Specific Aspects of Urban Form and Built Environment

14.3.1 Pilot Area 1 Legerova street

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Fig. 14.9 Prague

Legerova Street represents a corridor with the width of 25 m, surrounded by 21 m high buildings. The traffic density is approximately 45 000 cars per day in 4 lines. The street leads through a residential area in north-south direction. During summer months it is fully open to sunshine and the incoming solar energy is largely absorbed by asphalt and concrete as well as by facades of the buildings. There are only a few sparse parts of grass beds and no availability for shade (Figs. 14.9 and 14.10).

Implementation of tree alleys was assessed as a mitigation measure. Three different scenarios varying the form and position of the alleys were tested in cooperation of Prague Institute of Planning and Development, Czech Hydrometeorological Institute, and the Department of Meteorology and Environment at Faculty of Mathematics and Physics, Charles University in Prague.

Besides the thermal comfort, also the air pollution concentrations were taken in mind. The initial NO_x concentrations in Legerova Street could reach ca. 33 $\mu g/m^3$ on the east windward sidewalk and even around 160 $\mu g/m^3$ on the west leeward sidewalk due to the prevailing west wind direction which causes this unbalanced air pollution dispersion.

The thermal comfort was simulated by using of the microclimate model RayMan (Matzarakis et al. 2010). The ventilation conditions for air pollution were simulated by a model developed at the Department of Meteorology and Environment, CUNI Prague.

Fig. 14.10 Aerial view of Legerova street in Prague

A mild summer day of 21st June 2013 was chosen for the simulation of all proposed scenarios. Temperature effect was also modelled on a tropical day of 18th June (Fig. 14.11).

The simulation results for all scenarios in the mild summer day ($T_{A,max} = 26$ °C) show a possible effect of PET reduction of 2.3° in shade. During the tropical day ($T_{A,max} = 37$ °C) the reduction can reach 3.5°. However, all scenarios show also more or less negative impact on the ventilation conditions for air pollutants.

In the scenario with small trees positioned densely along the sidewalks, there is quite short time period of shade provided to one assessed point. On the other hand, the street canyon ventilation in not worsened noticeably (Fig. 14.12).

The effect of PET reduction in the scenario with large trees along the sidewalks lasts for a longer afternoon period due to a larger shade. However, the large crowns significantly impact the air flow and cause a serious concentrations increase on the windward sidewalk (Fig. 14.13).

The simulation of the scenario with an axial position of small trees in one row in the centre of the street shows no impact on PET, providing no shade on the sidewalks. At the same time, this arrangement constitutes an obstacle to the vortex and thus causes additional increase of already worse high concentrations on the leeward sidewalk (Fig. 14.14).

High trees in the street bring more shade with a positive effect on PET, but also create less favourable ventilation conditions. The scenario with the small trees planted densely along the sidewalks seems to be the optimal solution for UHI mitigation for Legerova Street. This scenario does not have such a negative effect on ventilation conditions and provides shade and a positive effect on PET.

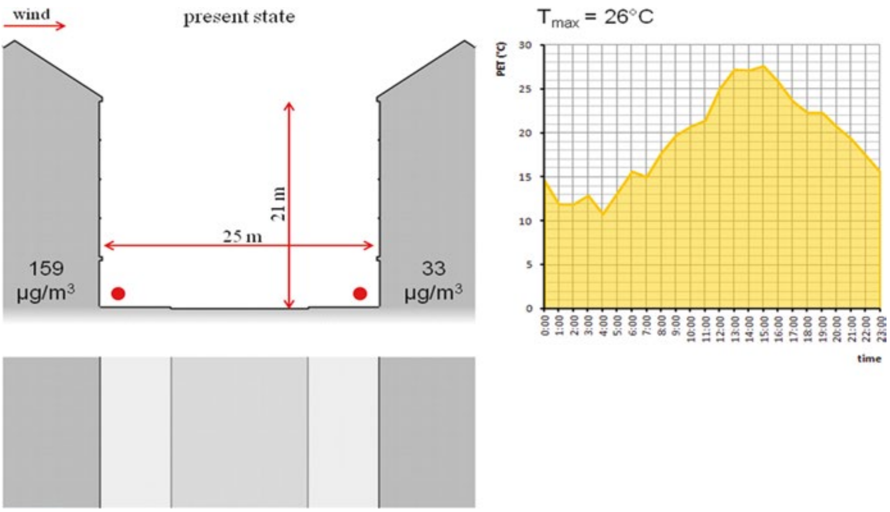

Fig. 14.11 Mild summer day scenario

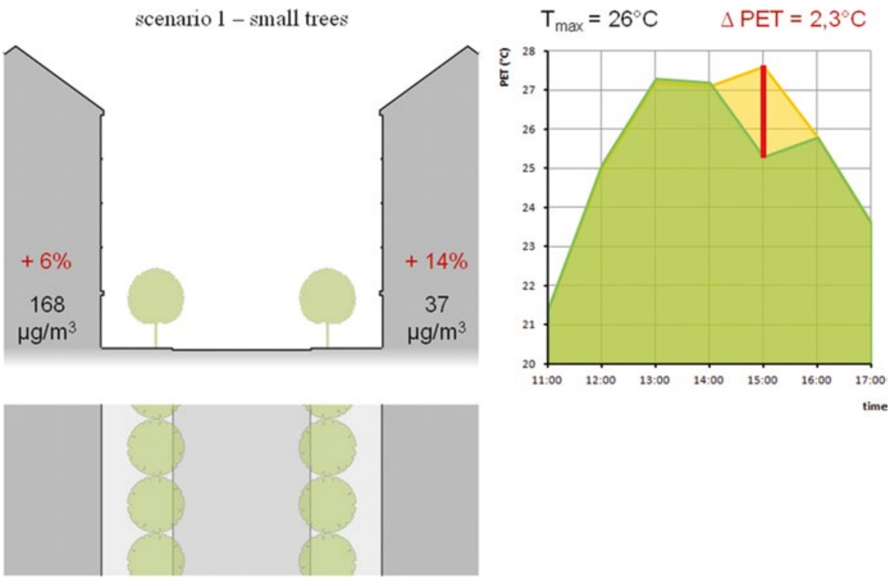

Fig. 14.12 Effect of PET reduction

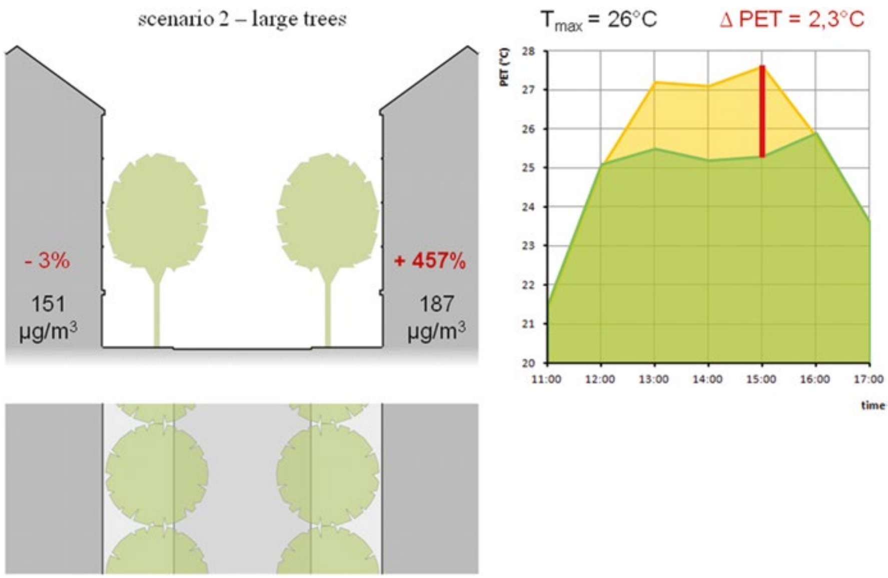

Fig. 14.13 Scenario 2

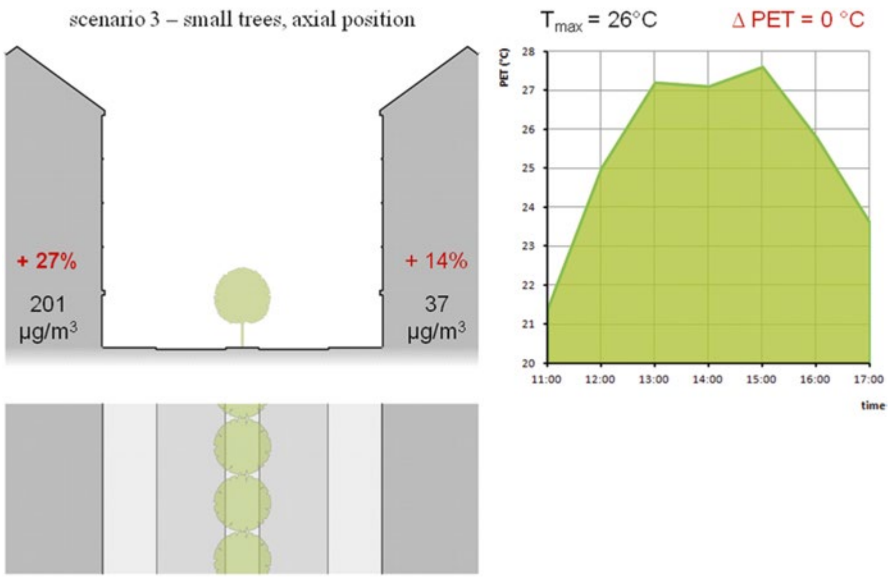

Fig. 14.14 Scenario with the small trees planted densely along the sidewalks

14.3.2 Pilot Area 2 Holešovice – Bubny

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Lokalita Holešovice – Bubny

Holešovice – Bubny was chosen to be one of the Prague's pilot areas due to its strong development potential and proximity to the city centre. Once used as a freight station the site is nowadays a brownfield that aspires becoming a living city quarter. A significant part of the area is occupied by the transport infrastructure, the rest is scattered with isolated buildings and fragments of block structure. Existing greenery is not properly maintained. In the east and west the site is adjoining various urban structures and the Vltava River in the north and south. The selected pilot area is about 82.5 ha large (Fig. 14.15).

The site is considered to be the future residential and commercial district. According to the current urban study the area shall be converted into a block structure, accompanied by small-scale parks and alley-like streets. Mean building height (between 25 and 26 m) shall be pierced with several landmarks (height from 50 up to 70 m). These adjoin to park areas as well as to the northern river bank. Existing railway tracks shall be reduced and elevated to enable streets to pass beneath (Fig. 14.16, 14.17 and 14.18).

The aim of the research was to examine the benefits of the current study (scenario 1) and to compare it with alternative urban studies proposing different urban structures and larger park areas (scenarios 3 to 6) (Fig. 14.19, 14.20 and 14.21).

In terms of land use, greenery types and building characteristics the following GIS models were performed:

Scenarios 3 and 4 propose a massive east-west oriented park strip located in the middle of the pilot area. A loose urban structure with high buildings of small footprints adjoin to the park in the north (Fig. 14.22).

This arrangement should leave more space for greenery and enable better ventilation of the area.

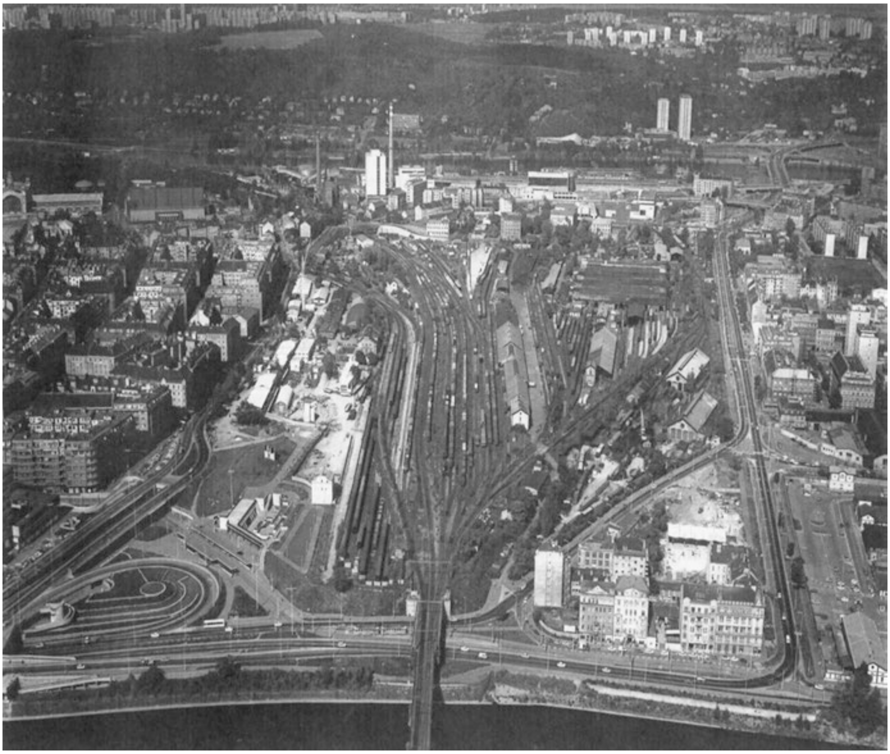

Fig. 14.15 Future residential and commercial district

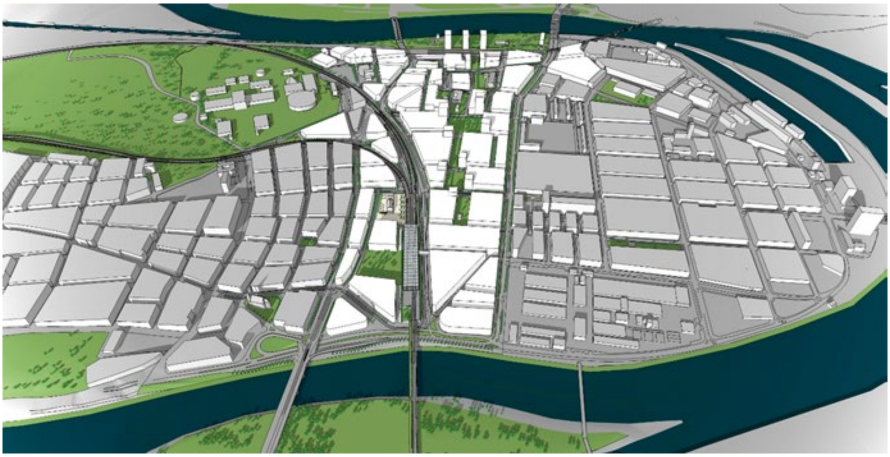

Fig. 14.16 Series of small-scale parks shall by hooked up through alley-like streets

Fig. 14.17 Inside yards of housing blocks shall be used for greenery and be walkthrough

Fig. 14.18 Scenario 1

Fig. 14.19 Scenario 2

Similarly to the current study scenarios 5 and 6 propose a block structure combining it with another arrangement of the central park: (Figs. 14.23 and 14.24)

In collaboration with the Meteorological Institute of the University of Freiburg and ATEM Prague following microclimate models were carried out with use of the ENVI-met software. The models simulate life conditions 1.5 m above the ground level during the day with the strongest insolation on June 20th at 3.00 PM.

We are conscious that the following conclusions are badly one-sided. For acquiring more realistic climatic conditions it would be necessary to perform a higher number of simulations.

Street canyons shaded by buildings have cooling effect (depending on the aspect ratio): (Figs. 14.25 and 14.26)

Wide streets not surrounded by buildings and not shaded by trees have a desiccating effect:

Fig. 14.20–14.21 (Scenario 3 and Scenario 4)

Busy streets have a warming effect due to the heat output from motor transport (see the bottom Fig.). Still water basins have no cooling effect: (Figs. 14.27, 14.28, 14.29, 14.30 and 14.31)

As mentioned above the block structure offers better day time conditions than the loose urban structure. However further research should explore the cooling effect of the parks during the night time.

14.3.3 Green Belt

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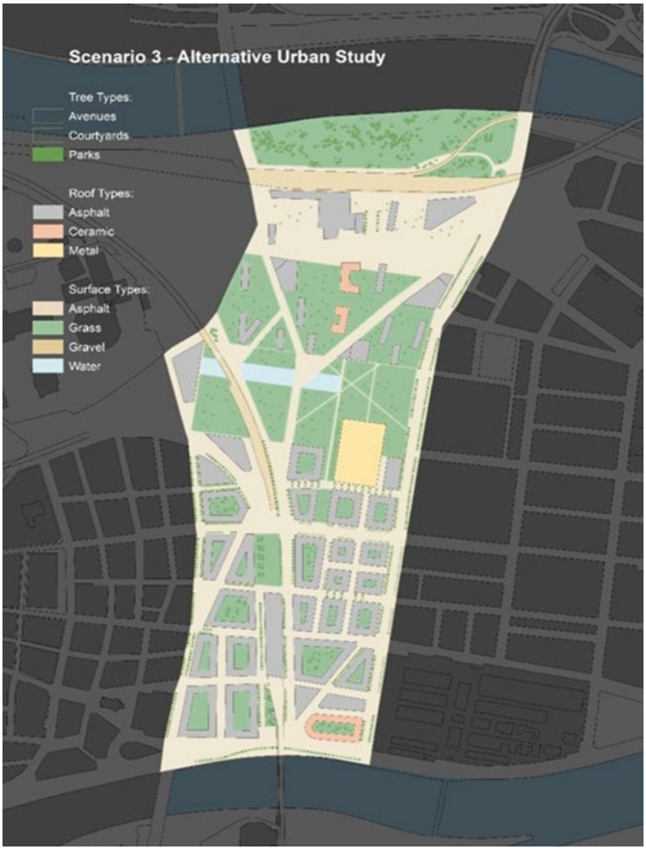


Fig. 14.22 Better ventilation scenario

The assessment was focused on the issue of modelling of meteorological fields and air quality in conditions of conurbation with regard to presence of urban heat island phenomenon. Within the project framework, modelling tools for air quality evaluation were tested while meteorological parameters and chemistry of the atmosphere were taken into account. Based on the acquired findings from the base state, the horizon of fulfilment of land use plan in its present form and the variants of urban and traffic concept were assessed.

The project assessed the following scenarios: baseline state, fulfilment of the land use plan, low-emission zone and implementation of a green belt. In addition, sensitivity to the expected climate change was studied.

In terms of UHI, the most important was evaluation of green belt scenario, i.e. state when the transport concept and vehicle fleet composition corresponds to the year 2020 and fulfilment of the land use plan is presumed with the exception of areas defined as green belt whose land use is assumed to be changed into forest area or forest park.

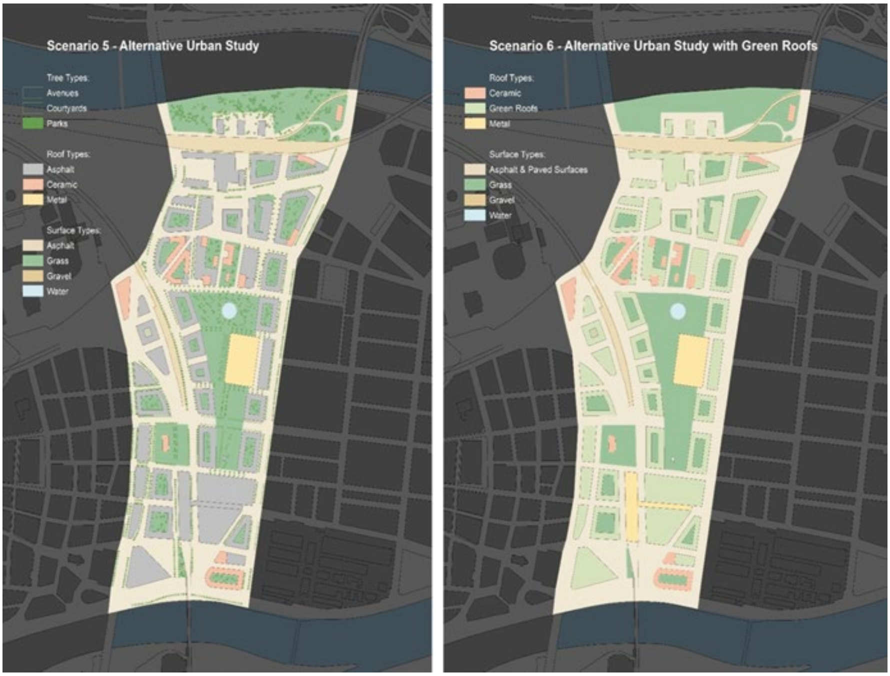


Fig. 14.23–14.24 Scenario 5 and Scenario 6

The method used for modelling of transport of chemical substances required to include a large territory in which boundary conditions were modelled, influencing meteorological quantities and concentrations of pollutants within the area of interest. The entire modelled area covered Europe, i.e. area measuring 4 644 × 3 294 km with its centre being located in Prague. Assessment with the finest resolution was carried out for Prague and its surroundings where grids of 1 km and 333 m were used.

Input data for the project were prepared in such detail that has not yet been realized. For this purpose, data from regularly updated study Evaluation of Air Quality in the Territory of the Capital City of Prague Based on Mathematical Modelling as well as data about the area of interest provided by the IPR institute and available databases from other sources were utilized.

The project involved both modelling of meteorological fields using the WRF model and modelling of air pollutant dispersion using the CMAQ model. The meteorological model was con Fig.d with an urban surface impact model; the emission flux model contained an anthropogenic emission model, a biogenic emission model, a chemical transport model and modules of data post processing and statistical processing of the outputs. For long term experiments, urbanized RegCM was used with 10 km resolution, allowing SUBBATS (Pal, J. S., F. Giorgi, X. Bi, N. Elguindi, F. Solomon, X. Gao, R. Francisco, A. Zakey, J. Winter, M. Ashfaq, F. Syed, J. L.

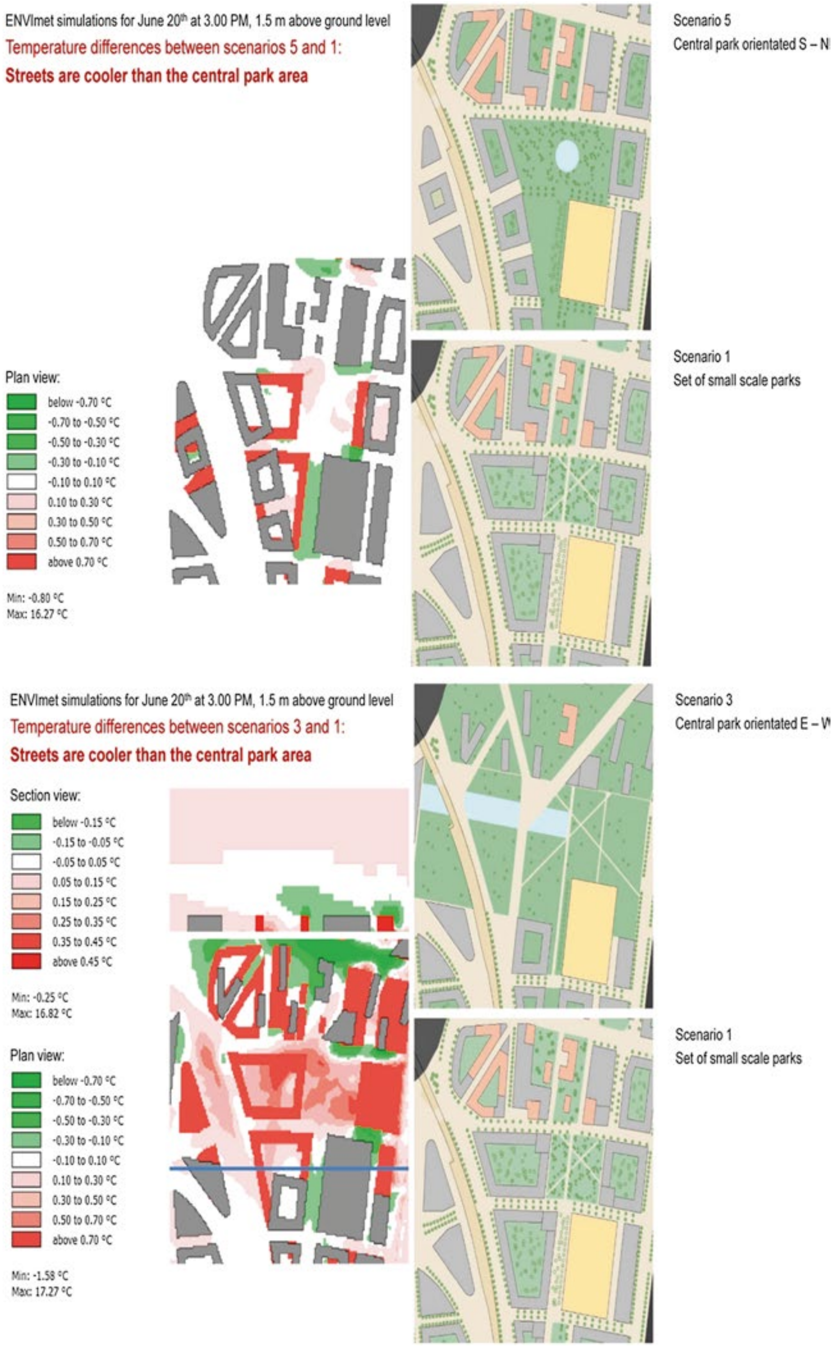


Fig. 14.25–14.26 Scenari

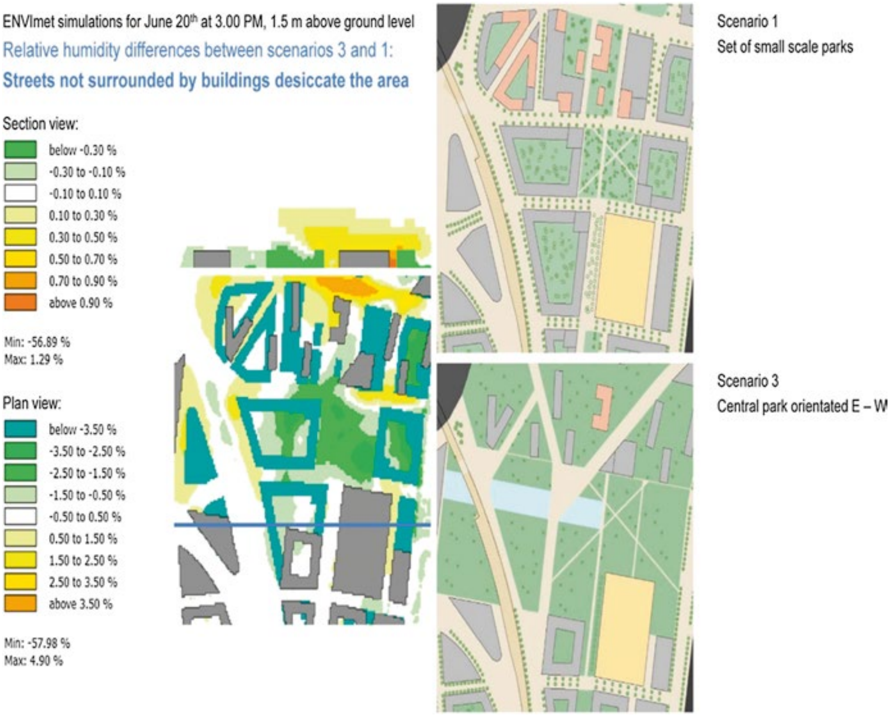


Fig. 14.27 Scenari 1/3

Bell, N. S. Diffenbaugh, J. Karmacharya, A. Konare, D. Martinez, R. P. da Rocha, L. C. Sloan and A. Steiner, 2007: The ICTP RegCM3 and RegCNET: Regional Climate Modeling for the Developing World, B. Am. Meterol. Soc., 88, 1395–1409) in 2 km.

Both meteorological parameters (temperature, humidity, wind speed) and concentration of pollutants were modelled.

Outcomes of the assessment allow evaluating not only long-term indicators (annual average) but also characteristics that have not yet been assessed sufficiently accurately, such as exceedance period of an air pollution limit and n^{th} highest values of short-term average values in accordance with legislation. Also ozone concentrations can be evaluated. The results are available both for current state, for future scenario of land use plan and other scenarios being assessed.

The evaluation points out the following:

By 2020 or by the horizon of land use plan fulfilment, respectively, reduction of concentrations of pollutants in Prague can be expected with the exception of vicinity of large transport structures where the impact of newly introduced car traffic outweighs.

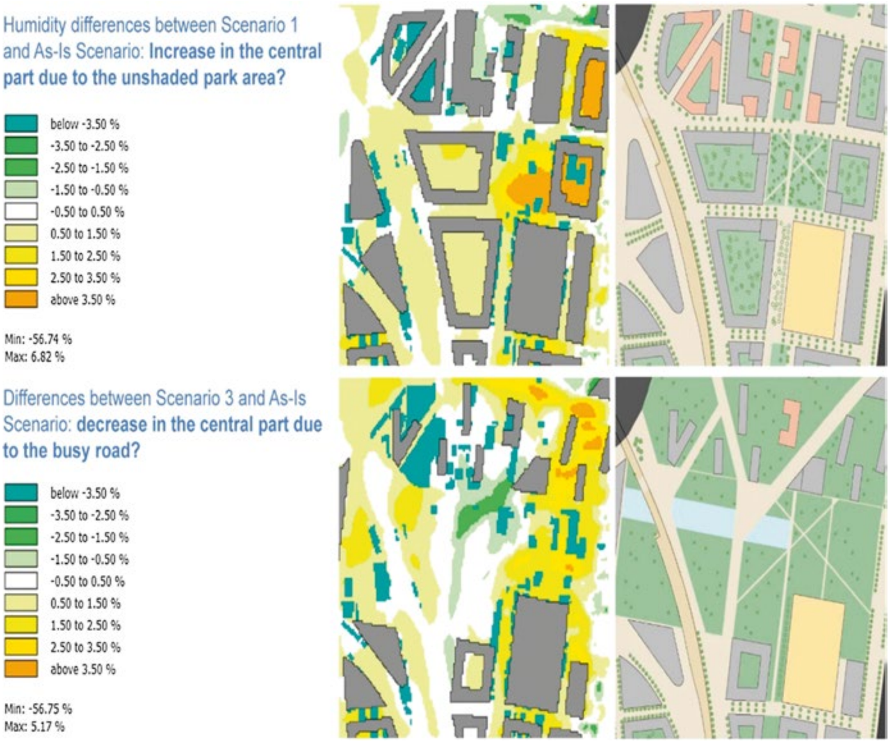


Fig. 14.28–14.29 Humidity differencies

Improvement in vehicle fleet composition has a positive effect on NO_2 and suspended particulate matter concentrations and also on benzene (but less). In the case of ozone, the peak concentrations (which are limited in terms of health) decrease and average annual concentrations increase (higher concentrations at night time).

The evaluation showed that secondary aerosols have a relatively high contribution to air pollution load by suspended particulate matter. This issue requires further specification because higher concentrations of PM_{10} are one of the major problems of air quality protection in the capital city of Prague.

The influence of the green belt is rather small; it affects only few sites by small decrease in temperature and consequent change in concentrations of pollutants

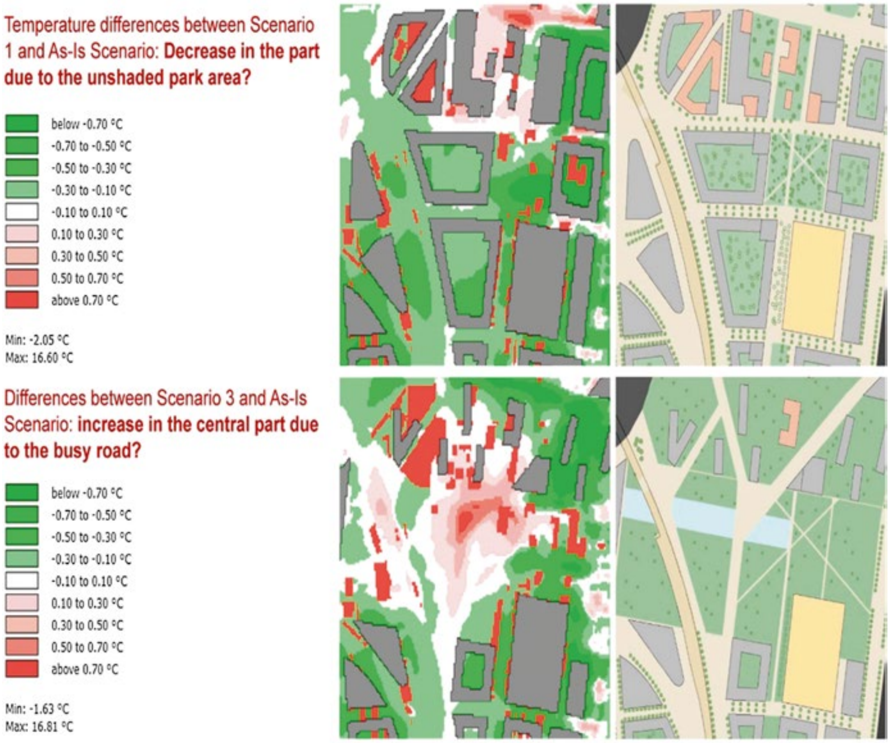


Fig. 14.30 The cooling effect of green roofs is negligible

caused by a change in biogenic emissions production and by a change in chemical reactions in the atmosphere. Certain changes can be seen in long term simulation, with small temperature decrease, especially in summer night. Remote effects are rather climatic noise. Changes in the future go with the overall temperature change, but they are again rather small.

The presented project practically verified the potential use of chemical transport models for air quality and UHI assessment in a small scale. The fine resolution that reaches up to 333 m for the innermost domain allows assessing air quality and UHI effect in cities in detail.

Proposed green belt around Prague (Figs. 14.32, 14.33, and 14.34).

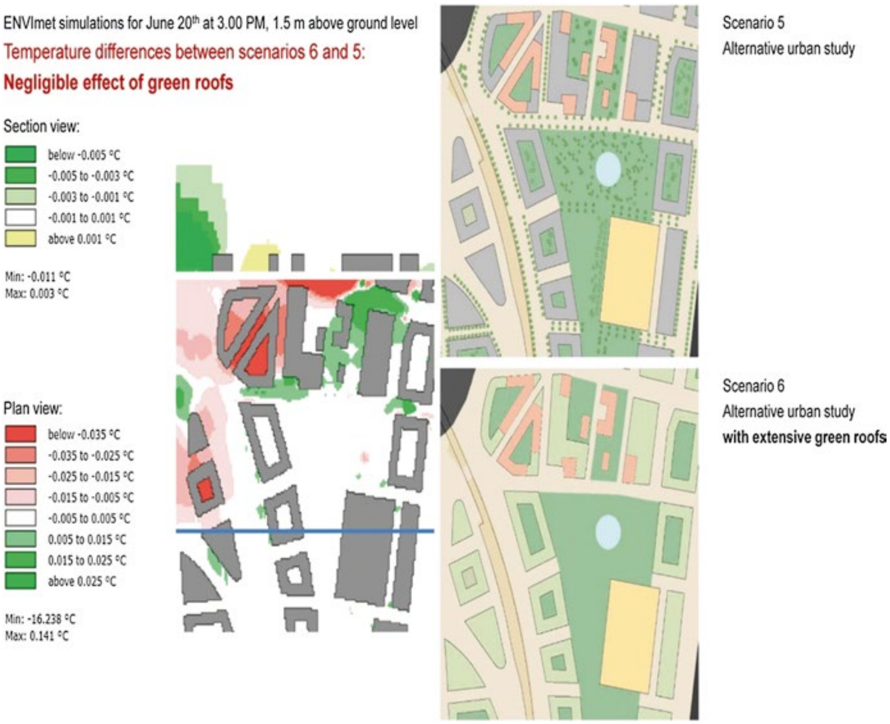


Fig. 14.31 The block structure offers better day time conditions

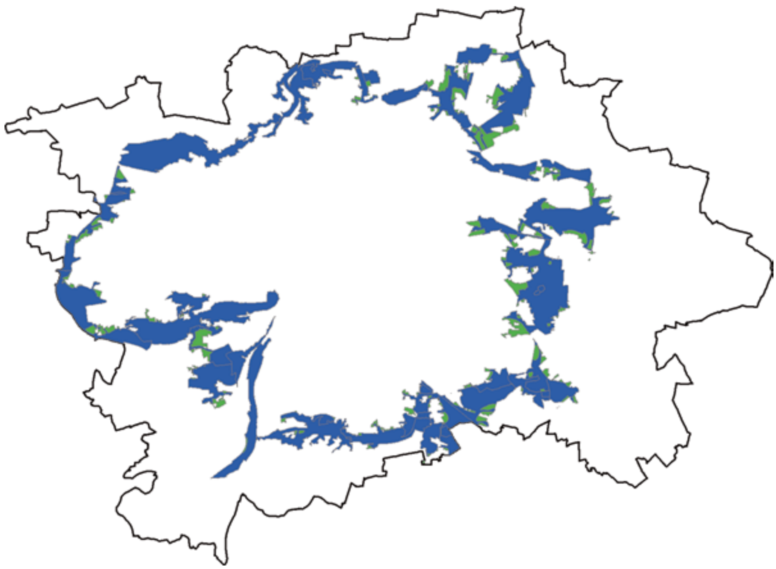


Fig. 14.32 Temperature shift caused by green belt in a hot July day

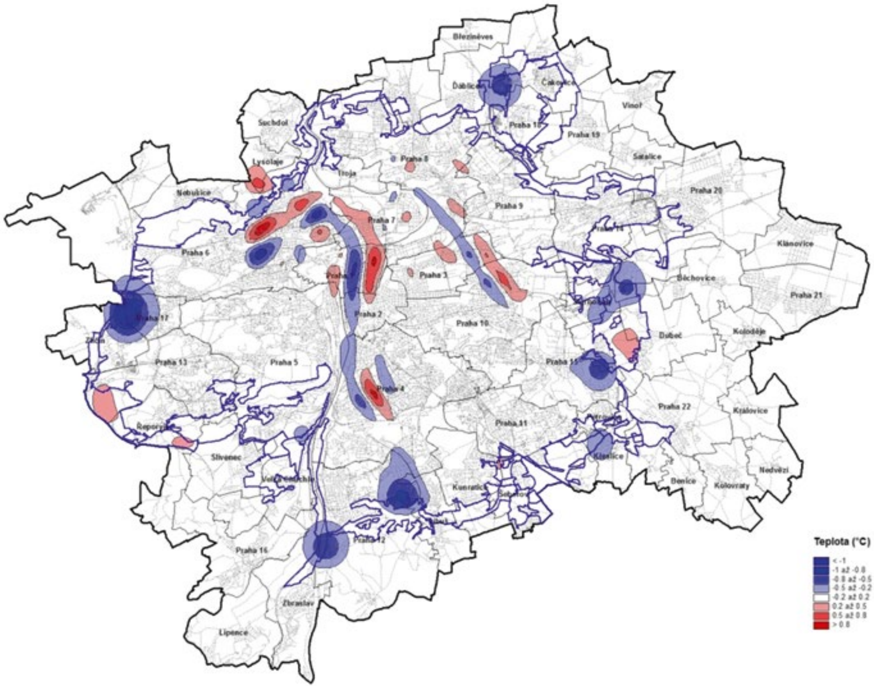
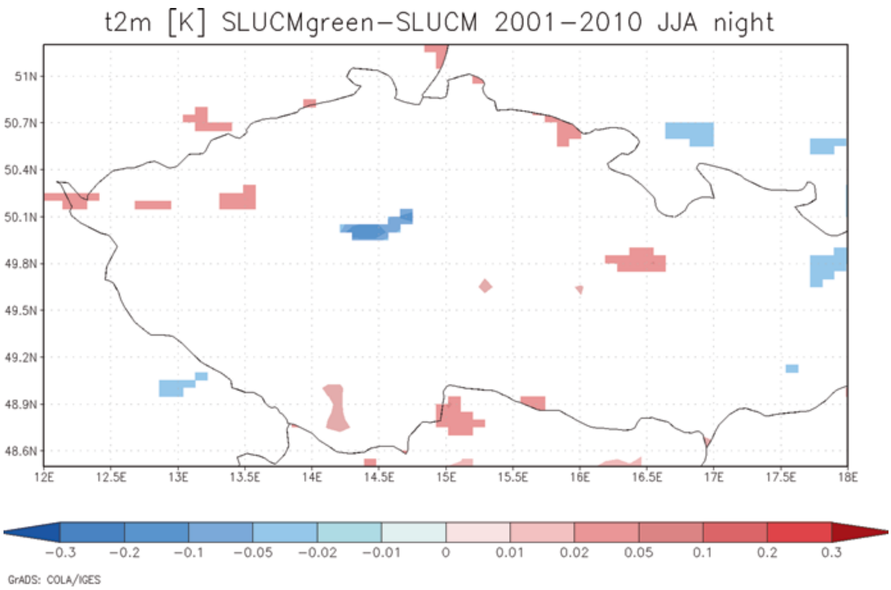


Fig. 14.33–14.34 Temperature changes in long term simulation of 2001–2010 (JJA, night) caused by green belt



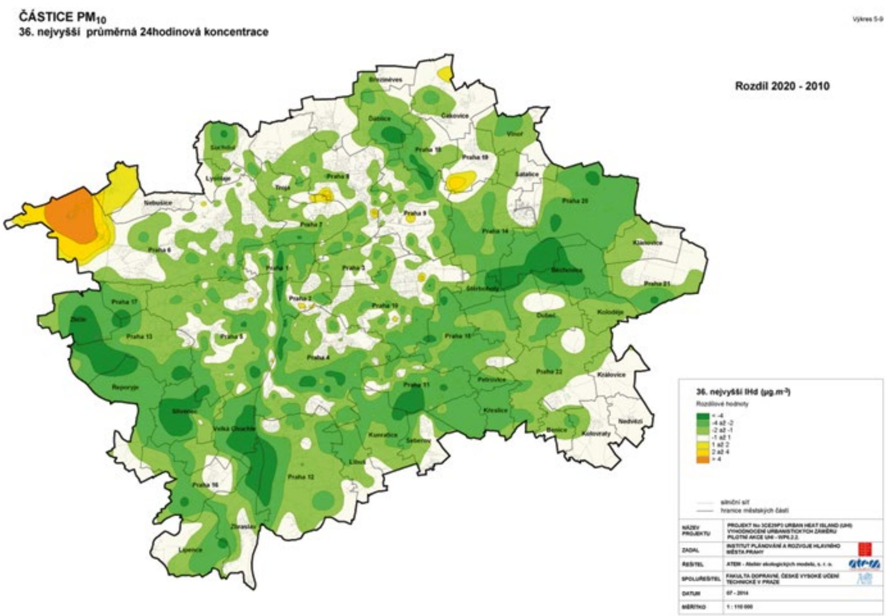


Fig. 14.35 Differences in 24-h-averaged PM_{10} concentrations

Differences in 24-h-averaged PM_{10} concentrations between years 2010 and 2020 (Fig. 14.35).

14.4 General Strategic Vision to Mitigate UHI Effects-Counteracting Measures

14.4.1 Street Canyons

As a result of the simulations, the scenario with the small trees planted densely along the sidewalks seems to be the optimal solution for UHI mitigation for Legerova Street and other similar street canyons with a heavy traffic volume. This scenario does not have such a negative effect on ventilation conditions and provides shade and a positive effect on PET.

14.4.2 Development Areas

The aim of the research was to examine the benefits of the different scenarios compared with alternative urban studies proposing different urban structures and larger park areas.

The simulations have shown that the block structure offers better day time conditions than the loose urban structure. However further research should explore the cooling effect of the parks during the night time.

14.4.3 Green Belt

The assessment of the effect of a proposed green belt as a scenario for UHI mitigation in Prague was focused on the issue of modelling of meteorological fields and air quality in conditions of conurbation with regard to presence of urban heat island phenomenon.

Within the project framework, modelling tools for air quality evaluation were tested while meteorological parameters and chemistry of the atmosphere were taken into account.

In terms of UHI, the most important was evaluation of green belt scenario, i.e. state when the transport concept and vehicle fleet composition corresponds to the year 2020 and areas defined as green belt are assumed to be changed into forest area or forest park.

The method used for modelling of transport of chemical substances required to include a large territory in which boundary conditions were modelled, influencing meteorological quantities and concentrations of pollutants within the area of interest

The project assessed the following scenarios: baseline state, fulfilment of the land use plan, low-emission zone and implementation of a green belt.

The presented project practically verified the potential use of chemical transport models for air quality and UHI assessment in a small scale. The fine resolution that reaches up to 333 m for the innermost domain allows assessing air quality and UHI effect in cities in detail.

As a result of the recent modelling, the influence of the green belt showed to be rather small; it affects only few sites by small decrease in temperature and consequent change in concentrations of pollutants caused by a change in biogenic emissions production and by a change in chemical reactions in the atmosphere. Further simulations with traffic modifications are needed. It should be pointed out, that the effect of climate change for the year 2020 is negligible compared to the effects by changes in land-use and transport concepts with vehicle fleet changes.

Adaptation strategies to contrast bioclimatic emergencies were included in a proposition for the Prevention plan in cooperation with the State Institute of Health. The proposition of the Prevention Plan includes the instructions for people, especially for sensitive groups how to react and what measures to take in extreme hot periods in cities.

The proposed HEAT Warning System will help to coordinate adaptative strategies and the reaction of City Authoritities to the extreme weather phenomena as to protect citizens against the harmful effects of heat and the UHI.

Reference

Matzarakis, A., Rutz, F., & Mayer, H. et al. (2010). Modelling radiation fluxes in simple and complex environments – Basics of the RayMan model. *International Journal of Biometeorology, 54*, 131–139.