

Chapter 12

Urban Heat Island in the Ljubljana City

Blaž Komac, Rok Ciglič, Alenka Loose, Miha Pavšek, Svetlana Čermelj, Krištof Oštir, Žiga Kokalj, and Maja Topole

Abstract Ljubljana made the first climate mapping of the city in 2000, putting the differences in terms of UHI effects between the inner part of the city and the surrounding areas are quite evident. An efficient planning of city infrastructure takes into account increasing average temperatures in a city, and therefore provides solution to reduce and monitor the effect of its urban heat island. The chapter presents the urban heat island in the Ljubljana region, temperature modelling based on satellite data and UHI project pilot actions in the Ljubljana city.

Keywords Urban heat island • Urban heat island atlas • Satellite thermography measurements • Pilot actions • Ljubljana • Slovenia

12.1 Introduction

Urban heat island is an urban area where temperatures are higher than in the surrounding area. This is mainly due to the accumulation of heat in buildings, concrete and asphalt land during the day. This leads to a greater night long wave radiation from the surface and thus to a smaller cooling than the surroundings (Žiberna 2006). The city also has lower albedo, greater diffuse solar radiation due to pollution, reduced evapotranspiration and lower relative humidity which influences quality of life (Ravbar et al. 2005; Tiran 2016).

B. Komac (✉) • R. Ciglič • M. Pavšek • M. Topole
Anton Melik Geographical Institute ZRC SAZU, Novi trg 2, 1000, Ljubljana, Slovenia
e-mail: blaz.komac@zrc-sazu.si

A. Loose
Energy Manager of the City of Ljubljana, City of Ljubljana,
Adamič-Lundrovo nabrežje 2, 1000, Ljubljana, Slovenia

S. Čermelj
Department of Environmental Protection, City of Ljubljana,
Zarnikova 3, 1000, Ljubljana, Slovenia

K. Oštir • Ž. Kokalj
Institute of Anthropological and Spatial Studies ZRC SAZU,
Novi trg 2, 1000, Ljubljana, Slovenia

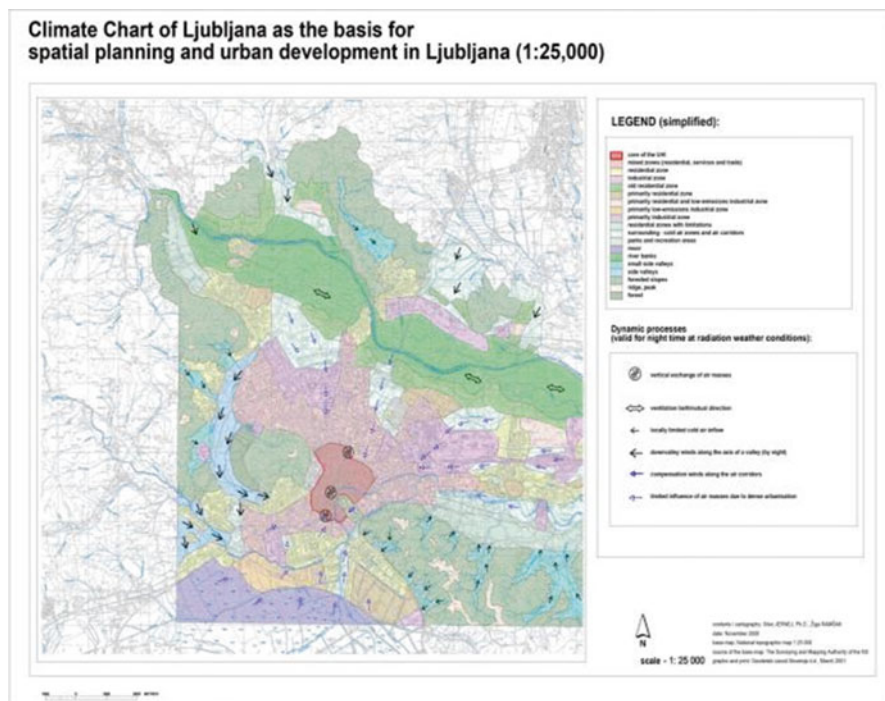


Fig. 12.1 Climate chart of Ljubljana showing the urban heat island area

In Ljubljana, urban heat island was first detected when creating The climate map in 2000 (Fig. 12.1). Area with above-average temperatures was lying between the Rožnik and Golovec hills (Rejec Brancelj et al. 2005; Smrekar et al. 2016). In the context of climate map guidelines for spatial planning were prepared, which preserved the green wedges and fresh air corridors for the city centre (Internet 3).

During the UHI project we found that the development of the city and in particular the construction of many shopping centres with large parking places increased the intensity of urban heat island phenomenon. The project was designed primarily for mitigating as well as adapting to this phenomenon and thus climate change.

12.2 Meteorological Measurements

During the project the urban heat island index was calculated for the Ljubljana Bežigrad (46°07' N, 14°52' E, 299 m a.s.l.) and Brnik (46°22' N, 14°22' E, 364 m a.s.l.) meteorological stations (Internet 1). The Ljubljana Bežigrad weather station is within the inner circle of the city. The area is representative for a typical urban Ljubljana setting, 1.5 km away from the city centre. The weather station is a synoptic one and thus equipped with many for the UHI-recognition meteorological

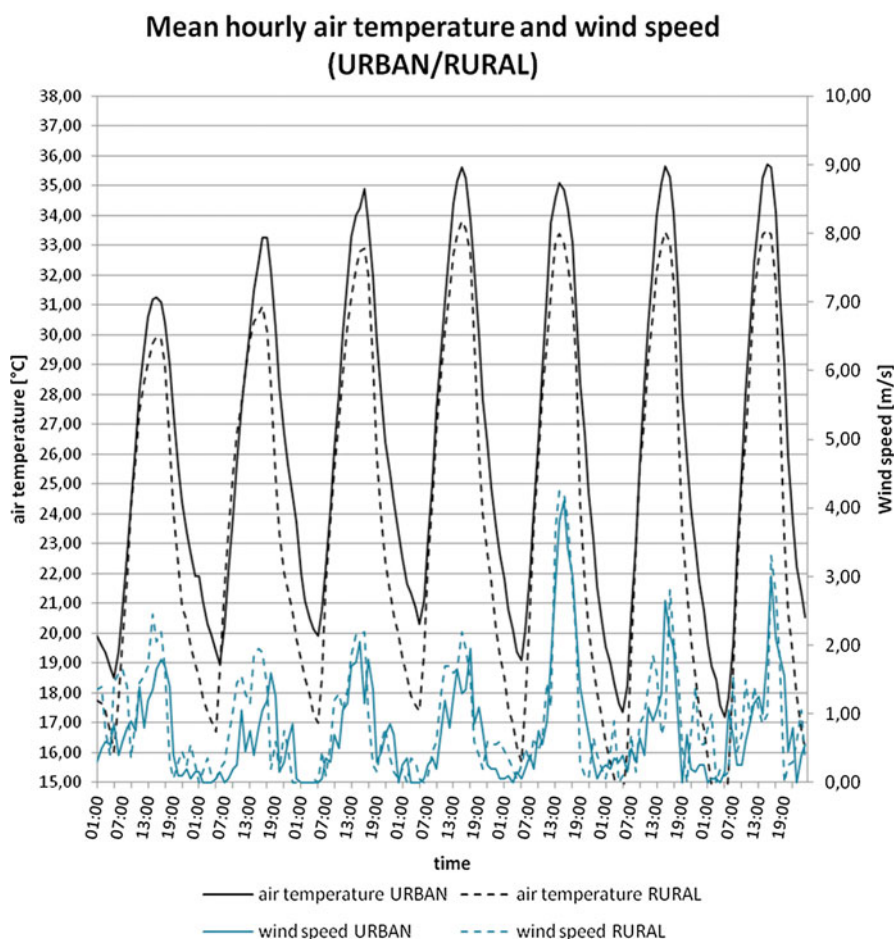


Fig. 12.2 Mean hourly air temperature and wind speed data in urban and rural station

devices (Internet 1). The Brnik weather station is in a complete rural area and stands on the SE edge of the Jože Pučnik Airport runway, over 100 m NW from it and more than 1 km away from the nearest bigger building. First larger forest area is over the airport's runway more than 500 m away. The surrounding terrain is in general flat, open and grassy. Weather station is a climate one and the measurements are taken automatically. The air distance between both weather stations is something more than 17 km; the difference in altitude is 65 m (Fig. 12.2).

The UHI intensity-cycle was calculated for the period July 20. to July 26. 2011. Its intensity was quite similar every day. The lowest intensity was present in the morning of the second day, when the heating at the rural station has started earlier than at the urban station and it was significantly more rapid. Before a midday the urban station became warmer, but in the evening rural station was cooling significantly faster. That caused that UHI intensity has reached the third highest

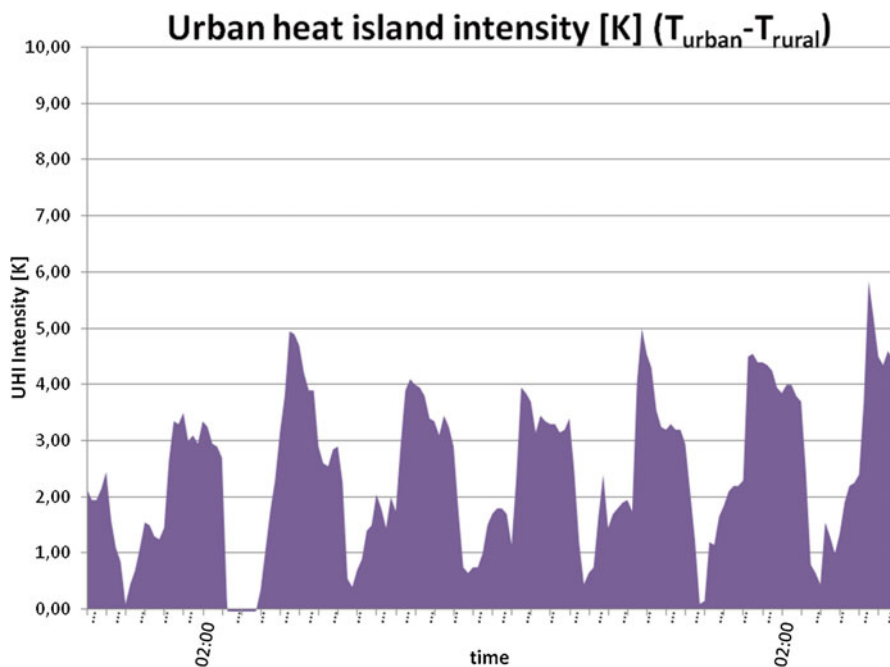


Fig. 12.3 Mean urban heat island intensity data

value in the selected period (4.95 K). A little higher air humidity compared to following days in the period was probably a cause for thin-fog formation near the middle of the night, which has decreased cooling rate at the urban site. In the whole period wind was varying from calm in the night/early morning time to the top speed around 2–3 m/s in the afternoon on the both stations. In the beginning of selected period the prevailing wind was weak mid-atmosphere NE winds, which usually doesn't reach the valley's bottom. That is why none of the stations shows a signal of constant NE winds. The measured wind variations were thus thermally driven by a daily heating and nocturnal cooling, because in the selected period the sky was clear all the time. The biggest anomaly of the wind in the selected period occurred during the day on the 24th of August, when the wind direction in the middle altitudes has changed to SW, which descends over the Dinaric Mountains to Ljubljana basin and has some characteristics of the foehn wind. Also the air humidity was the lowest in that time at the both stations. A weak SW wind was blowing till the end of a selected period and very low humidity has caused the lowest night-time temperatures especially at the rural station and thus the UHI intensity has raised for 0.5–2 K (Figs. 12.3 and 12.4).

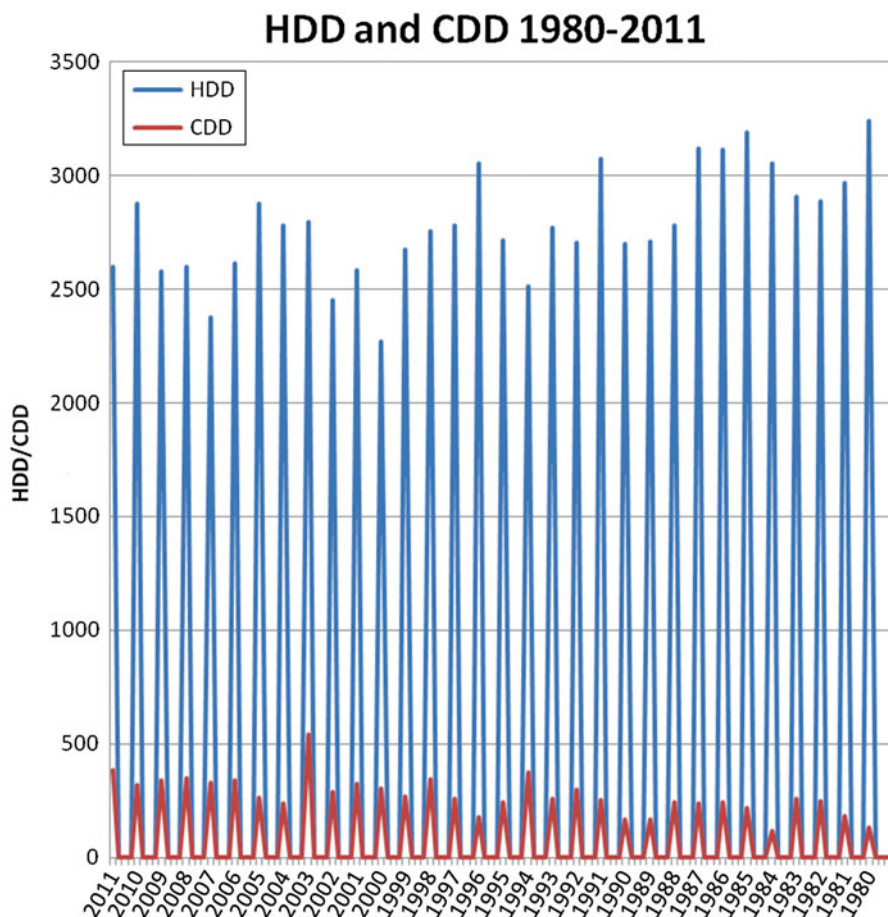


Fig. 12.4 Mean heat degree days (HDD) and cold degree days (CDD) in the period 1980–2011 for Ljubljana

12.3 Satellite Thermography Measurements

Efficient planning of city infrastructure and its activities has to take into account increasing average temperatures in a city, and therefore consider and monitor the effect of its urban heat island (Zakšek and Oštir 2012).

Land surface temperature can be monitored with satellite systems (Colombi et al. 2007). To assess the extent and state of urban heat island of Ljubljana we used Landsat 8 imagery that has adequate spatial resolution for a detailed analysis of temperature variations (Bechtel et al. 2012). Images of Ljubljana and its vicinity are acquired twice every 16 days. Land surface temperatures were calculated from two cloudless images per season in the period between April 15th 2013 and March 8th 2014.

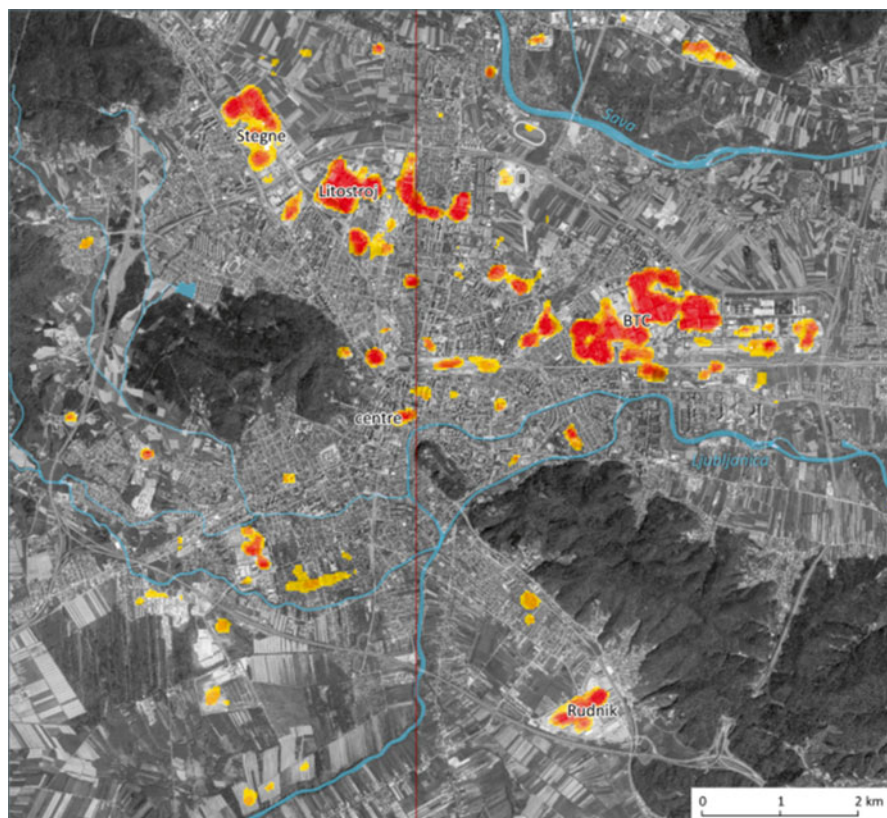


Fig. 12.5 The frequency of occurrence of the top two percent of the highest temperatures in built-up areas

The area of interest was divided into three zones, with the first being inside the city ring road, the second a 3 km band from the first, and the third a 2.5 km band from the second. The zones have been further divided according to land use; we have grouped the classes into: built up, water, agricultural land, and forest. Built up and water areas smaller than the resolution of the thermal band (1 ha) were excluded from the analysis. The first zone was further partitioned to city districts, and the second and third zones to areas of settlements.

Comparison of temperatures included built up areas of smaller cities close to Ljubljana (Kranj, Domžale, Kamnik, Grosuplje, and Vrhnika) and some of the city's more interesting regions (the centre, industrial areas, business-shopping centres, areas of individual housing, and parks). The impact of water and trees on the surrounding surface temperature was assessed with profiling – across the whole city and through specific areas of interest.

We have found that Ljubljana exhibits a distinct urban heat island. Furthermore, some of its districts are constantly warmer than others, and specific areas are definitive hot spots (Figs. 12.5 and 12.6).

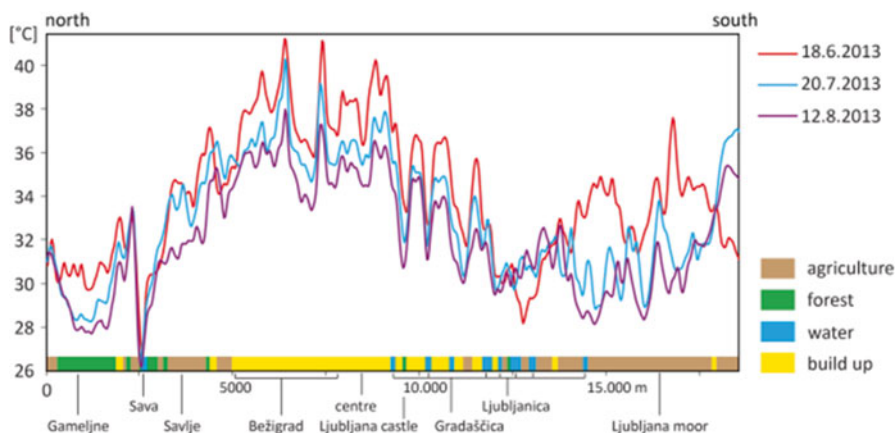


Fig. 12.6 Profiles of summer land surface temperatures across Ljubljana, with indicated land use and prominent orientation points. The location of the profile is marked as a *red line* on Fig. 12.5 but it extends beyond the boundaries of the figure

12.4 Urban Heat Island Atlas

The Urban heat island atlas is an internet application for visualization of spatial data, related to urban heat island in the area of Central European countries (Ciglič and Komac 2015). The database was elaborated in GIS environment using ArcGIS Desktop and published online using ArcGIS Server. This project result is intended to support decision-makers in the field of spatial planning and is therefore free-accessible to everyone at <http://zalozba.zrc-sazu.si/p/1352>.

The atlas presents urban heat island influencing factors including elevation, normalized difference vegetation index, land use (Corine land cover and Urban atlas data), human activity shown by night scene image (detected by VIIRS sensor data), air temperature at 2 m and land surface temperatures (Komac and Ciglič 2014).

Viewer can analyse the data by making profiles across the temperature layers for April and August (at 2 p.m.). In this way, temperatures in the city and the surroundings can be compared (see the example of Ljubljana in Fig. 12.7).

Various local and regional datasets provided by the project partners are also presented in the atlas.

The atlas was prepared by the Anton Melik geographical institute ZRC SAZU and Hungarian meteorological service.

12.5 Mitigation of the Urban Heat Island in the Ljubljana City Area

The purpose of the project was to establish the existence of a heat island, which was confirmed by data from meteorological stations and satellite thermography, and then use this knowledge to mitigate the effects of heat islands.

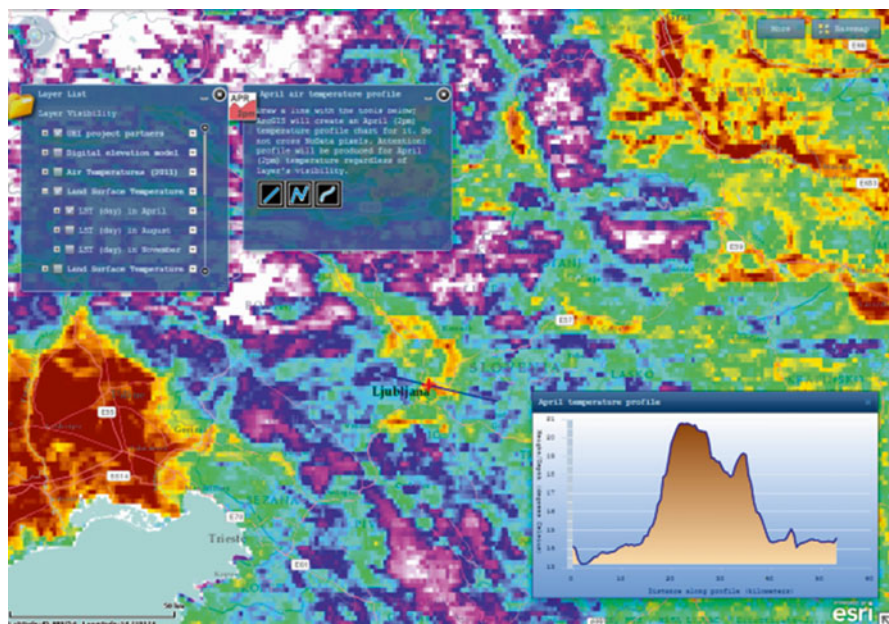


Fig. 12.7 Print screen of the Urban heat island atlas. Its user friendly interface enables users to select between different layers, make profiles across April (*as below*) and August temperatures in Central Europe and zoom to UHI partner data

As urban island is affected by several factors such as green areas in the city, location and design of the land use, types of building and roofing materials, layout of buildings, and their energy efficiency, including spatial development of the city, we examined some of the characteristics of the city of Ljubljana. We carried out some pilot actions to draw attention to the importance of taking into account the effects of the urban heat island in the planning of land use and activities in the city. In 2010 the Municipal spatial plan (Internet 2) was adopted defining the planned land use with special focus on urban land uses and future development of green areas (Fig. 12.8).

In order to minimize the effects of the urban heat island the basic strategic objective of the Ljubljana city is to create an interconnected and transparent network of open public spaces of high quality. During several last decades an action called »Ljubljana – My Town« has been under way. It stimulates the facades' renovation all over the important public areas or representative areas.

One of the most important measures is preserving the city green areas and protecting the city forests as a part of green wedges. A specific feature of the city is its green ring, a way along barbed wire, which encircled the city during the WW2 being a popular recreational area. The focus area is the axis along the river of Ljubljanica and green areas along the Sava river, the Gruber's canal, the Špica bank, and the Gradaščica and Glinščica brooks.

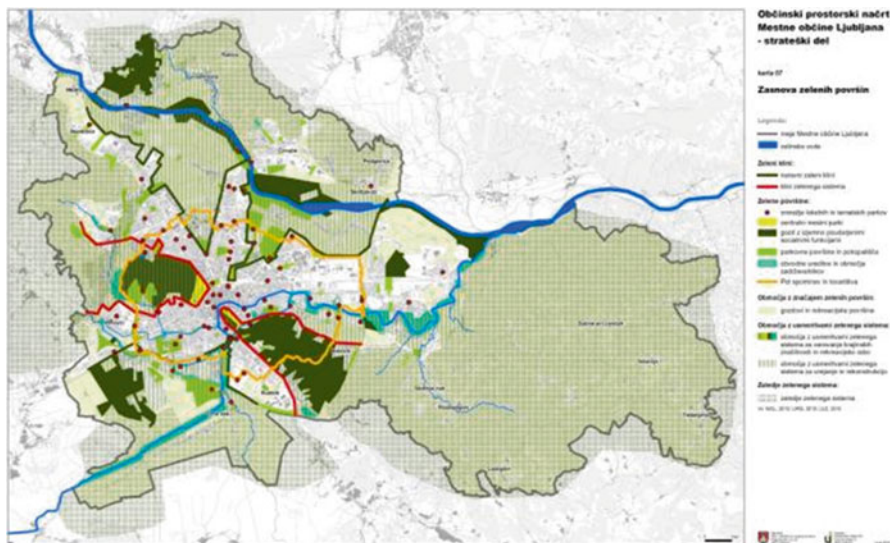


Fig. 12.8 Future development of green areas in the City of Ljubljana (Internet 3)

Related to green areas a special attention is given to open public areas network that connect the surrounding of the city with its squares, streets, riverbanks and walkways, and also serve as an air-corridor network. They create micro-climatic and mesoclimatic conditions, enable ventilation of the city. The stretches of waterways also constitute a system of open public spaces. Adequate directions for protection and management are defined for such areas.

The extent of pedestrian areas increased lately due to the traffic limitation and complete stop in inner city centre. Still, poor airing is presented in the Ajdovščina area. The city planning measures regain pedestrian areas that would make various social interactions possible. Urban ventilation is therefore an important factor of urban heat island mitigation, and connecting natural areas in landscape parks with the city.

In Ljubljana garden-plot areas were spontaneously developed and distributed across the entire flat area of Ljubljana. Due to a urban lifestyle and a policy change by the city authorities, the area of garden plots fell considerably at the end of the twentieth and the beginning of the twenty-first centuries. Until recently garden plots were spread on 200 locations and covered 1.3 km² (Jamnik et al. 2009) Due to pesticide residues and heavy metals in the soil and produce, as well as groundwater contamination, plot gardening poses a threat to public health and the environment, and the 2008 Ljubljana Zoning Implementation Plan reduced the total area of plot-gardening areas by nearly half.

Another way of minimizing the effects of urban heat island is related to building and roofing materials. The majority of old buildings in the centre of the Ljubljana city are built of bricks and stone. In the broader city area concrete buildings were built in the 1970' and 1980', while iron was used to build some new high buildings.

Most of the stone and brick buildings in the old city are plastered, while stone was used primarily for portals, window frames and in some cases, pet mats. Mitigation is difficult due to the fact that the Ljubljana centre was declared a cultural and historical monument, which requires full protection of the cultural, aesthetic, historical and natural values (Decree ... 1986). Common roofing material in Ljubljana is tiles. Tiles cover the majority of older buildings in the centre of the city. Some atriums of the buildings have been covered by glass and only few buildings and winter gardens have been equipped by green roofs until now, built mostly by incentives of individuals (Črnuče, Lek pharmaceutical company, Maros company) or by public funds (Stožice sport park a green roof with size 8000 m²).

12.6 Pilot Actions

The notion of spatial organisation as a method of urban management has been adopted in three typical areas of the City of Ljubljana: the city centre, suburban area and hilly hinterland. This division is merely schematic as it would be difficult to demark these areas where the contents are intertwined (Decree ... 1986).

In Ljubljana 21 streets in the centre of the city have been closed to traffic since 2006. The public cycling system Bikelj has been established in 2011. In some areas in the city centre the allowed speed of traffic was reduced to 30 km/h, allowing safer cycling and pedestrian transport.

The 2010 Municipal spatial plan defines land use activities from urban land use, green areas, cycling routes and green areas points of view.

A number of drinking fountains were established in the city centre next to several fountains. In 2010 two new parks measuring 15 ha have been established: the Northern park and the park at the Šmartinska street. The city of Ljubljana is taking care of more than 72,000 trees in the city and its surroundings. More than one hundred trees were planted in the streets of the city centre in 2009 and more than 250 trees were planted in 2010 as a part of a project the Labyrinth of Art. About 1409 ha of forests on the nearby hills (Rožnik, Šišenski hrib, Grajski grič, Šmarna gora and Grmada) were given a status of forest of special importance, although almost 90 % of the forests are a property of private subjects. Next to a new stadium and sport hall about 90.000 m² of green areas (parks and sport areas including cycling and running tracks) next to 5000 m² of play grounds are going to be built. Also, the Ljubljanica river banks were reconstructed in order to allow public access to water in the city. Large areas of the city dump in the Ljubljansko barje area were transformed to golf links (<http://www.ljubljanapametnomesto.si/>). A list of buildings which are accessible for disabled people has been made public (<http://www.disabledgo.com/sl/org/ljubljana>).

The determination of pilot Urban Heat Island installations locations was a subject of numerous consultations and debates within the City administration and public. Some of them were realized in 2013, the others were prepared and installed this year.

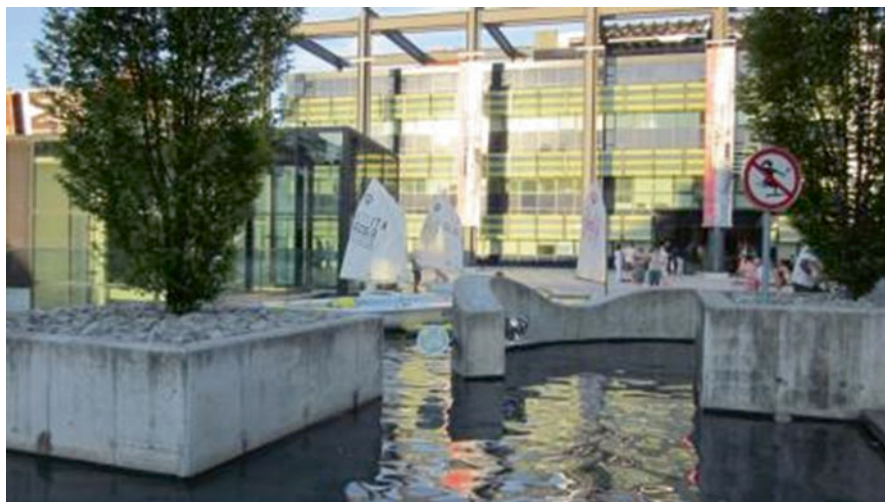
12.6.1 Ambient Urban Intervention “Boats in the Fountain” on the Plateau in Front of Slovenian Ethnographic Museum (SEM), June, 2013

The architectural concept of the plateau in front of the SEM in the very city centre is a part of a collage of various surfaces and objects. Some of the surfaces are less used than expected, as is the case of the 260 m² plateau, that was planned as a water surface, but was not realized for years. In the summer period, water is one of the most important elements of public space – it cools the ambient and represents an ideal playground for children. Water also reminds us on holidays, sea, boats, ..., and is especially attractive for children. For those reasons we have decided to restore the project and to realize the long-time ago planned water surface in an innovative way that will be attractive for public.

In June 2013, the ambient intervention “Boats in the fountain” was realized, by:

- re-establishment of water surface,
- establishment of spaces where it is possible to play, work or rest,
- rearranging the area to bring it closer to the children and adults.

For the installation old boats were used, after the detailed renewal, each of them had its own name and own story. It became an ideal meeting place for all generations. Throughout the whole summer period numerous visitors enjoyed the vicinity of water surface, especially children. The project was concluded by the end of September (Figs. 12.9 and 12.10).



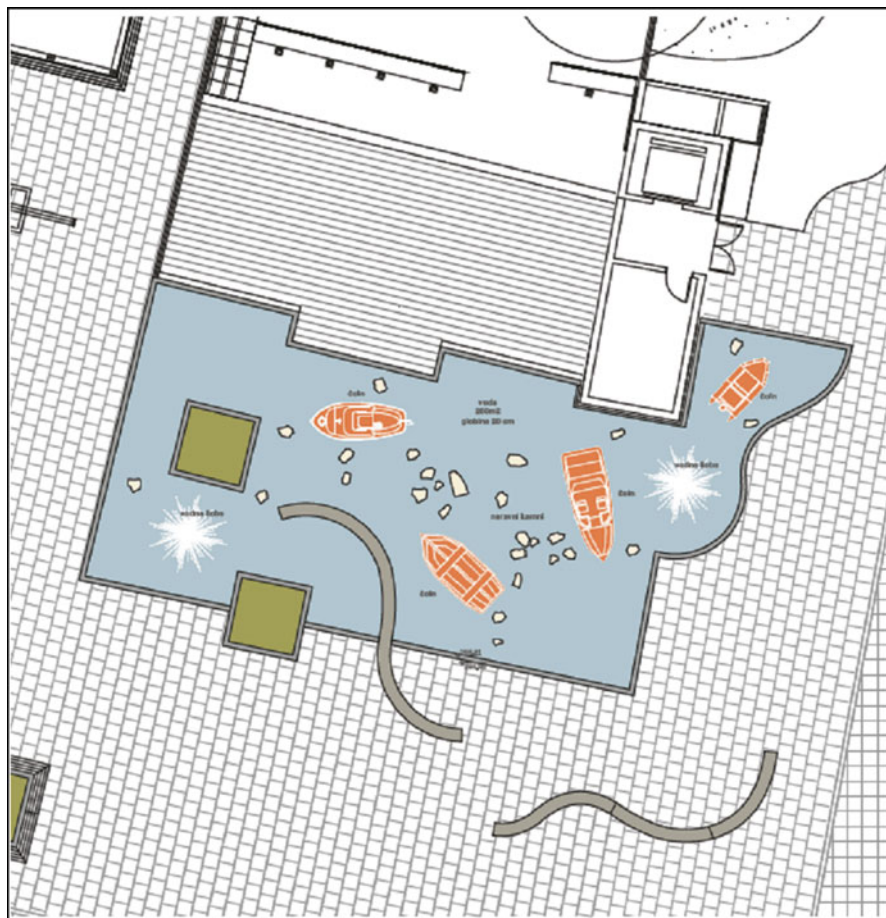


Fig. 12.9 Project baseline – Slovenian ethnographic museum (SEM)



Fig. 12.10 SEM – realized water surface

12.6.2 Temporary Installation on the Central Section of the Slovenska Street after its Closure to Traffic (September 2013)

Since September 22, 2014, the central part of Slovenska street, passing through the very city centre was closed to motorized traffic, with the exception of public transport. With this measure the transit of motorized vehicles is being reduced in the city centre and the priority of using it is given to pedestrians, cyclists and public transport. On the occasion of closing the street a temporary arrangement was designed and realized to show the citizens and tourists what they can gain from the street closure. The project of temporary arrangement was planned in a sustainable way according to the principle “Less is more” (or “More with less”). All elements may be moved from one location to another, whenever needed. Besides street markings no element will be used for the Slovenska street only. Temporary arrangement comprised of:

- information point (Info point) about new arrangement of the Slovenska street – citizens were invited to give additional proposals for additional installations or improvement of the existing,
- potted groups of trees (wooden pots),
- smaller permanent green plants in pots – pocket parks,
- Tables and chairs,

An info point-container in which the exhibition of the projects concerning the new look of the street was prepared together with the exhibition showing the history of the main street. Numerous citizens and other visitors gave their proposals for improvements and compliments. It is important that the citizens were satisfied with new arrangements, using the newly gained space daily. With additional plants (green areas) an effort was taken to improve local environmental conditions and to establish more attractive street ambient. The black-carbon and nitrogen dioxide measurements were performed on-site as well (Fig. 12.11).

12.6.3 Green Gym – Gymnastic House with Green Roof (April 2014)

The prototype of small green gymnastic house with green roof was designed and built. It was designed for adults, to be placed on public playground for children to serve for parents and other adults while their children are playing. The time, usually spent waiting for children on the bench, has changed into the active/healthy recreation and can serve as an example of a good practice for children, as well. The gym-house is placed on recently renewed playing ground in the city centre.

The gym-house was named “Always young” has a base of 6 m² and is about 3 m high. It consists of the metal construction that serves as well as a gymnastic object,



Fig. 12.11 Temporary installation on the main street (Slovenska ulica) soon after its closure to personal motorized traffic

solid roof planted with extensive growing grass on wooden base reinforced by metal sub-construction. As the installation is placed outside, the rain will be enough for the watering of the roof. In the house a simple construction consisting of three basic gym equipment suiTab. for both genders and ages are available. The gym house is funded on concrete foundation. Within the area of 1.8 m around house, material that buffers falls is spread. On the walls there is a Table with instructions how to exercise. As the gym-house is a part of the playground for children it was planned and built in such a way that it meets the standards (the gym-house is certified) (Fig. 12.12).



Fig. 12.12 Children and parents playground – the gym-installation for parents with the green roof was added to the classical playground for children, with the invitation letter (*right*)

Vabilo



*Ob Dnevu zemlje vas vljudno vabimo
na otvoritev prenovljenega otroškega igrišča
na Prulah, na Prijateljevi ulici,
v torek, 22. aprila 2014, ob 16.00 uri*

Tam nas bo pričakalo presenečenje - telovadna hiška z zeleno streho
za telovadbo staršev, babic in dedkov, pa še koga, ki se bo
najmlajšim pridružil pri igri. Pridružite se nam!
Z veseljem bomo delili dobro voljo z vami in z najmlajšimi iz Vrtca Pod Gradom.



V Ljubljani se vsak dan znova zavedamo pomembnosti varovanja našega planeta, kar z drobnimi in večjimi dejanji tudi uresničujemo. Telovadna hiška z zeleno streho je nastala v okviru evropskega projekta UHI, katerega namen je priprava in uporaba orodja za modeliranje pojave toplotnega otoka v mestu, ki bo služil predvsem načrtovalcem kot izhodišče za umeščanje dodatnih zelenih in vodnih površin v mesto, s ciljem zmanjševanja pregrevanja mestnega središča.



Mestna občina
Ljubljana



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12.6.4 Pocket-Parks in the Streets with Parking Places (April 2014)

Pocket parks are representing the long-term cultivation of public-spaces. With these installations we are trying to develop a method for revitalization and remediation of degraded spaces in the built part of the city centre. The interventions are not only artistic installations but also a serious search of new urban possibilities for better use of urban spaces. The main objective is to pay special attention and to reveal selected city areas.

Pocket-parks are a kind of containers with the dimensions of a single parking place (car) that can play a certain role, with its planted part, to mitigate the UHI phenomenon on the micro-scale within the densely built area in the city centre.

Since May 2014 it is possible to enjoy on one of the pocket-parks, called PARKplac (PARKplace) on four streets and one square. They are equipped according to the reuse concept. Local inhabitants and local merchants will take care about them. With these installations we are addressing the citizens to the new approach to the public space and spreading the 3R idea (Reduce, Reuse, Recycle). According to the 3R approach all materials that are used were taken from past installa



12.6.5 Planting Trees (April 2014)

By planting trees we are trying to increase the quantity of green areas in the city. Trees have been planted on three locations according to the standard SIST DIN 18916.

Near the Nove Fužine block-settlement the new park “Art Labyrinth” was planted. The Art labyrinth is bringing together the park as a green public area with the labyrinth art tradition, artistic approach and literature (book reading). The park is a kind of growing and development feature as it grows with its visitors. The more care that it is being given and the more trees that are planted, the bigger is the place where we can rest in peace and read a good book.



12.6.6 Promotion of the Project

On different occasions the UHI project was promoted (opening the pilot installations). One of them was also the project “For the cleaner city” that was taking place through the whole city area from 22th March to 22th April, 2014.



12.7 Conclusions

The urban heat island project gave us a comprehensive scientific insight in the phenomenon, useful tools and instructions for adaptation and mitigation of urban heat island effects. At the same time it was proved that our efforts in the past were successful preserving the important green areas (wedges) and fresh air corridors.

We are satisfied with a big success of the project that can be recognized by the number of people that were involved and mobilized by its activities.

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