“Implementation of a forecAsting System for urban heaT Island effect for the development of urban adaptation strategies” (LIFE ASTI)

Action C.4 **UHI Adaptation Strategies Assessment Report**

Thessaloniki January 2022

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Disclaimer

I Action C4

C4 action has a two-fold objective, which is to a) provide an assessment of the impact of future climate change scenarios on Urban Heat Island (UHI) for the two Mediterranean cities of Thessaloniki and Rome (UHI-FCAR) and b) to assess and quantify the outcome of promoting mitigation measures in the cities mentioned above to reduce/hinder the UHI effect (UHI-ASAR).

The current report refers to the second of the deliverables of the C4 action (UHI Adaptation Strategies Assessment Report, UHI-ASAR). For the purposes of this subaction/deliverable the climate of a reference and two future periods has been simulated via the Weather Research Forecast (WRF) mesoscale meteorlogical model, which was used as a Regional Climate Model (RCM). Then, a downscaling algorithm assisted in converting the model ouputs into a more realistic representation of the microclimate of the areas of study.

The present document assesses the impact of specific adaptation strategies applied to the cities of Thessaloniki and Rome. There is also a brief reference to the modelling system and the downscaling algorithm.

1) Tools and Methodology

a. Climate Model Set Up

The data used for this report were produced by the WRF model, which was applied over four two-way nested domains including Europe, Eastern Mediterranean Sea and the cities of Thessaloniki and Rome with a spatial resolution of 50km, 10km and 2km respectively.

The model was used to produce a reference simulation for the current climate over the period 2006-2010 and two future simulation over the periods 2046-2050 and 2096-2100. For the rest of this report, periods 2006-2010, 2046-2050 and 2096-2100 will be referred as periods A, B and C respectively. The lateral boundaries, which were used by the model for the simulations of both the control and the future periods, were obtained from the National Center for Atmospheric Research (NCAR) refering to the Representative Concentration Pathway (RCP) future scenario 8.5 [Bruyere et al., 2014]. In this scenario the greenhouse gas emissions and concentrations increase considerably over time, leading to a radiative forcing of 8.5 W m^{-2} at the end of the current century. A comprehensive description of the model and the various schemes used are included in the UHI-FCAR report.

b. Land Use

For the representation of the land use/land cover in the WRF model simulations, Global Land Cover by National Mapping Organizations (GLCNMO) and CORINE datasets [Tateishi et al., 2011; Hua et al., 2018] were used. For further information please see C4 UHI-FCAR report.

Here, we describe the CORINE dataset [Hua et al., 2018], which the work of this report is based on. CORINE dataset includes 11 urban classes (**Table 1**) and totally 44 land use classes, the distribution of which is represented in **Figure 1**) for Thessaloniki and Rome. For the analysis of the green intervention scenarios in Thessaloniki and Rome, class 1.1.1 of urban fabric (continuous urban fabric) was replaced by class 1.1.2 (discontinuous urban fabric) and 1.4.1 (green urban areas). Class 1.1.1 refers to areas of continuous urban fabric, i.e. areas in which impermeable features (e.g., buildings, rooads etc.) cover the surface by >80%; the rest of (up to 20%) may be covered by small squares of urban greenery. Then, class 1.1.2 is related to areas where artificially impermeable surface ranges between 30-80% land coverage; the rest of the area may be covered by sport areas and vegetated/green spaces. Finally, class 1.4.1 is used to represent areas with vegetation within or partly embraced by urban fabric, including parks with lakes and fountains with buildings associated to parks.

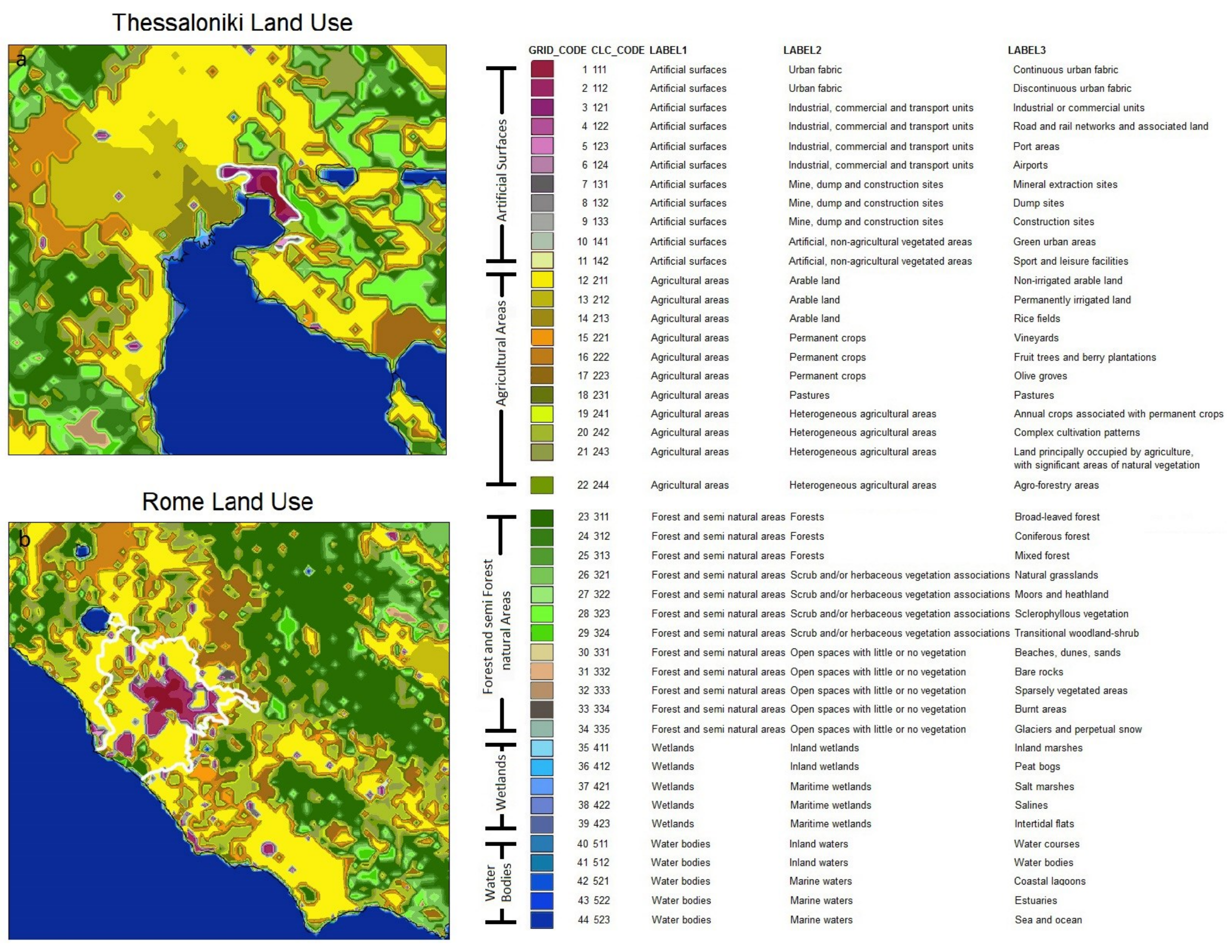

Figure 1 – Land use over greater areas of a. Thessaloniki and b. Rome according to Corine dataset.

Table 1 – CORINE urban land use categories

CORINE urban LULC classification
1.1.1: Continuous urban fabric
1.1.2: Discontinuous urban fabric
1.2.1: Industrial/commercial units
1.2.2: Road/rail networks and associated land
1.2.3: Port areas
1.2.4: Airports
1.3.1: Mineral extraction sites
1.3.2: Dump sites
1.3.3: Construction sites
1.4.1: Green urban areas
1.4.2: Sports and leisure facilities

c. Simulating the impact of interventions

A downscaling algorithm was deployed in order to refine the WRF model output from 2km to 250m over the two investigated urban areas. The downscaling algorithm was trained using weather station observations, which were firstly statistically analysed . Thus, areas of certain albedo and emissivity could be associated with specific change in temperature and relative humidity. The purpose of this process is to represent small areas, the land use of which is not dominant in a grid cell of 2x2km, in a more realistic way (e.g., a 150x150m green area within a 2x2km urban fabric).

Due to limitations regarding the weather station positions and the urban structure of the city of Thessaloniki, a different process was followed in this case. In particular, WRF model simulations for a summertime period in 2021 were run three separate times. The first simulation was conducted under the current lan use over the city, while for the second and third simulation a grid cell of land use class of 1.1.1, surrounded by urban fabric, was chosen and replaced by land use of classes 1.1.2 and 1.4.1, respectively. Then, the diurnal difference in temperature and relative humidity was calculated between classes 1.1.1 – 1.1.2 and 1.1.1 – 1.4.1.

A comprehensive description of the model and the various schemes used are included in C7 action deliverable (Report on the local pilot actions in Rome and Thessaloniki) .

d. The LIFE UrbanProof project

In addition to the aforementioned methodology, we selected the LIFE Climate Proofing Urban Municipalities (UrbanProof) project (LIFE Ref. No: LIFE15 CCA/CY/000086) in order to try evaluating the impact of the green interventions conducted by the municipality of Thessaloniki over the urban area. This project aims to the increase of resilience of municipalities to climate change providing them with a tool for supporting better informed decision on climate change adaptation planning. The tool (https://tool.urbanproof.eu/), provided by the project, consists of 5 stages: (a) climate change information; (b) impact assessment; (c) exploration and evaluation of adaptation options; (d) development of the adaptation strategy and (e) monitoring and review).

In this report, we used the stage 5 for heatwaves and health. In this tool the municipality of Thessaloniki (among other municipalities of Greece) is represented by grid cells of 500x500 meters (area of 250000 m^2) and each cell is coloured depending on the future human discomfort based on discomfort index "HUMIDEX" [Masterton and Richardson, 1979]. Within this tool there is the option to represent/calculate the human discomfort of green interventions introducing the area covered by them and the observed/calculated humidex over them.

2) Results

In this section we examine the results produced by the regional WRF model and the downscaling algorithm regarding the mitigation measures taken by the municipalities or the various possible scenarios of differentiating the materials and the land use within the urban fabric of the cities.

a. Thessaloniki

The municipilaty of Thessaloniki has already proceeded to several small-scale mitigation measures alternating the land use of areas within the urban fabric of the city (**Figure 2**). Green interventions together with the area that they cover and their impact on HUMIDEX, are shown in **Table 2**.

Table 2 – Green interventions completed by the municipality of Thessaloniki followed by covered area and their impact on average HUMIDEX.

Intervention Region	Area (m^2)	HUMIDEX average difference
Panastasiou & Voulgari Str	3726	-0.38
Mpotsari Str	3600	-0.39
26th High School	1500	-0.77
1st High School	6500	-0.77
Mavili Square	6466	-0.77

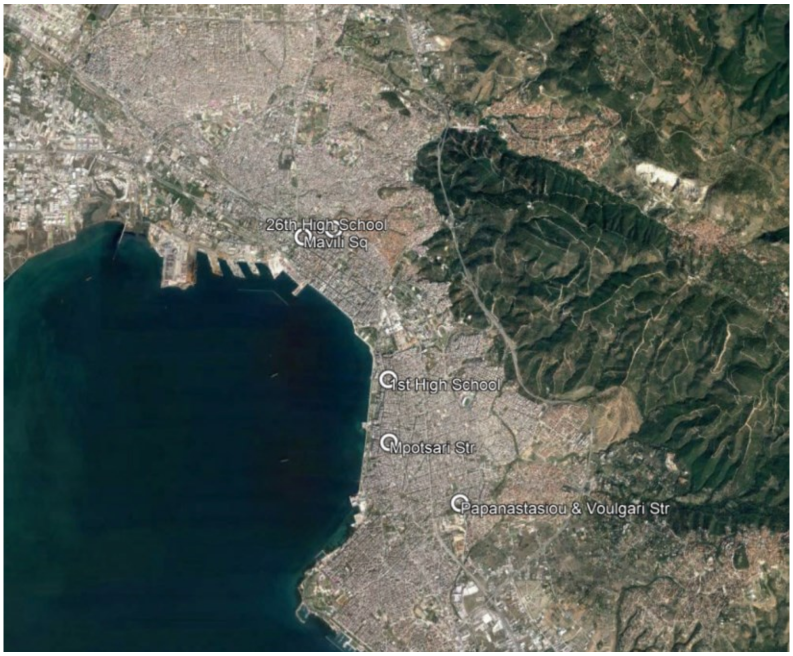

Figure 2 – Intervention point in the municipality of Thessaloniki

The above intervention areas can fall into two different categories, the urban green and the urban park, refering to land use 1.1.2 and 1.4.1 (see section 2). Papanastasiou & Voulgari Str and Mpotsari parks can fall into the category of urban park, while the rest of the interventions fall into the urban green category.

Having estimated the apparent temperature (Tapp) in the intervention areas as if they were urban (Tapp_urb) and green ones (Tapp_grn), their point effect in Tapp is calculated as the following difference:

Tapp_diff = Tapp_grn – Tapp_urb (1)

Both intervention types demonstrate a similar diurnal cycle with a maximum difference during the night and a minimum during the day (**Figure 3**). In particular, the largest difference is observed at 0UTC, being slightly larger for green urban green areas (-1.5°C instead of -1.4°C over urban park areas). However, urban green areas demonstrate lower Tapp by up to 0.4°C comparing to the urban green areas during the day (6-15UTC). It seems that urban parks keep Tapp lower (by ~-0.3°C) comparing to a dense urban area at the same place even during the day. In contrast, the urban green areas seem to exhibit similar or slightly higher Tapp (+0.1°C).

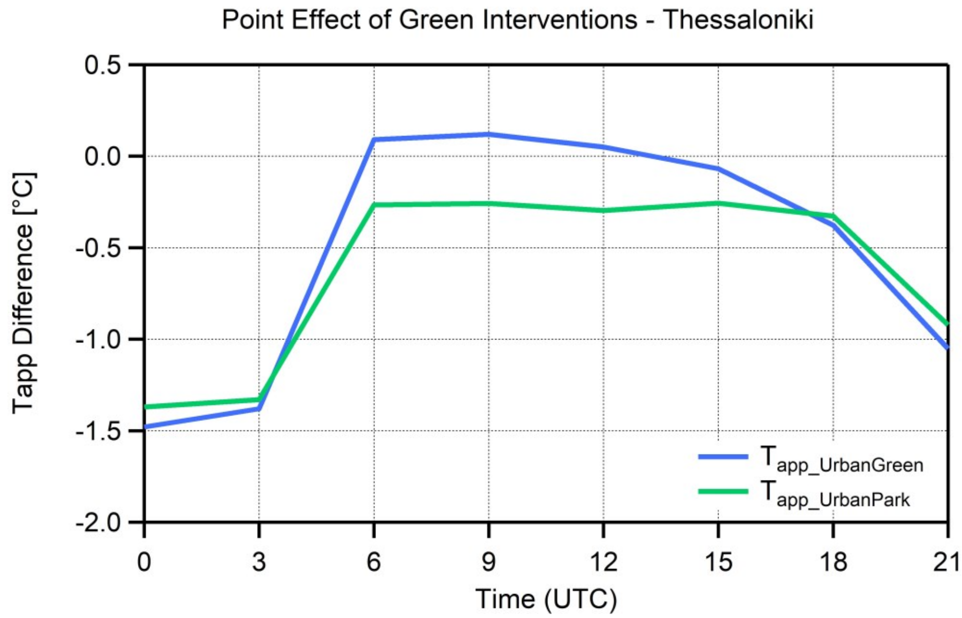

Figure 3 – Point effect of urban green (blue) and urban park (green) areas on Tapp for the city of Thessaloniki.

Alhough the effect of an intervention is significant at the area, where it takes place, this effect may decrease with the distance from this area. The effect radius may depend on a variety of factors, such as the extent of the intervention and the ventilation. Thus, it is important that such interventions will cover a significant part of the municipality of Thessaloniki in the future in order to affect its microclimate in total and not only over limited areas. Considering that the total area of the municipality of Thessaloniki is ~$20 \cdot 10^6$ m^2, it seems that covering 70% of this area with urban green interventions would decrease the average Tapp of the city by up to 1°C during the night. In case that the interventions area is limited to 30% of the urban area, then the maximum decrease in Tapp is by 0.4°C (**Figure 4**). An additional coverage of 10% by urban parks would cause a further decrease in Tapp by 0.14 during the night. During the day, as expected (according to the UHI definition), none of the intervention scenarios has an insignificant impact on Tapp.

According to the C4 UHI-FCAR report, average July Tappat 03UTC, in the city of Thessaloniki, is estimated at ~25°C under the present climate. This is expected to increase by +2.2°C and +4.8°C under the RCP8.5 scenario in 2050 and 2100 respectively. In addition, a scenario of covering the 70% of the area of the municipality by urban green and the 10% by urban park interventions could potential decrease the average Tapp by up to 1.2°C. As a conclusion, such an intervention scenario could mitigate the effect of climate change on the city. Thus, the expected increase for 2050 and 2100 could be +1°C and +3.6°C respectively.

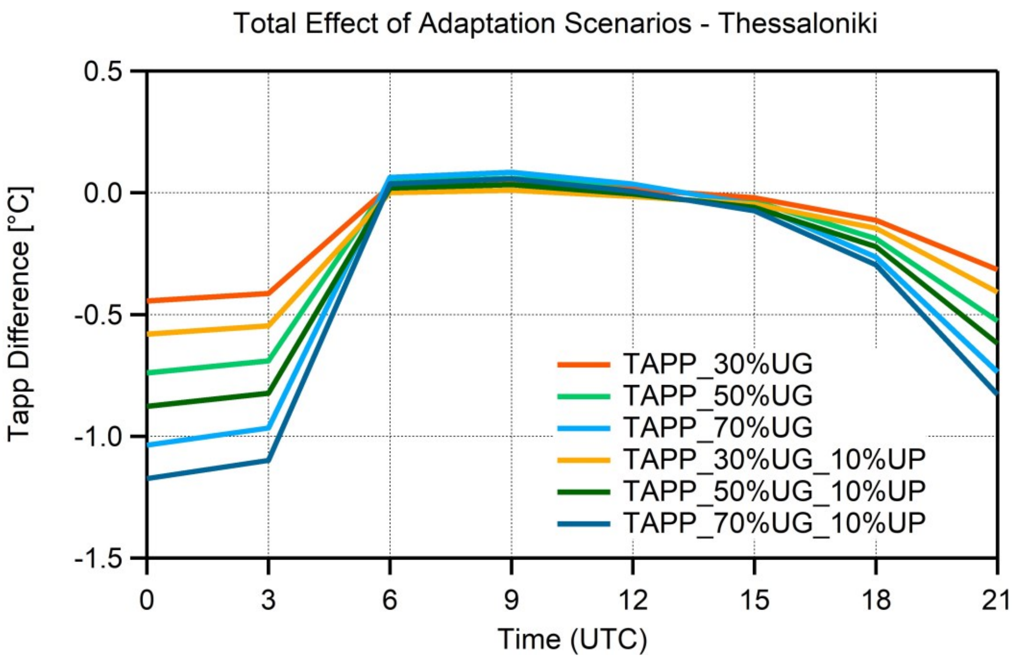

Figure 4 – Total effect of various mitigation scenarios in Thessaloniki. UG stands for Urban Green, while UP for Urban park areas. The percentage implies the percentage of the total urban area within the municipitality of Thessaloniki covered by the corresponding intervention.

Results produced through action C4 and C7 were used in the Urban Proof tool

In addition to the results presented in the previous sections, the impact of the green interventions already completed in the municipality of Thessalonik were evaluated using the tool developed in LIFE URBANPROOF. For this purpose, the humidex difference was calculated according to the results depicted in **Figure 3** and, then, it was introduced to the tool together with the intervention areas (**Table 2**). As the tool comes with a resolution of 500x500 meters, green interventions of 3000-6000 m^2 could not cause any effect on a cell of 250000 m^2 (**Figure 5**). Thus, the average human discomfort over the municipality remains at moderate levels (3.6468). This, compared to our previous analysis, reveals the need of higher resolution models in order to represent and evaluate small scale interventions within densely structured urban fabrics. Finally, it should be noted that according to the UrbanProof tool, an area of 250000 m^2 should be covered by different materials that would be able to decrease HUMIDEX by 8.9°C in order to turn the human discomfort from moderate into low to moderate (from 3.6468 to 2.7). However, we should take into account that the calculated value refers to daily average discomfort, while green interventions have their larger impact over the night.

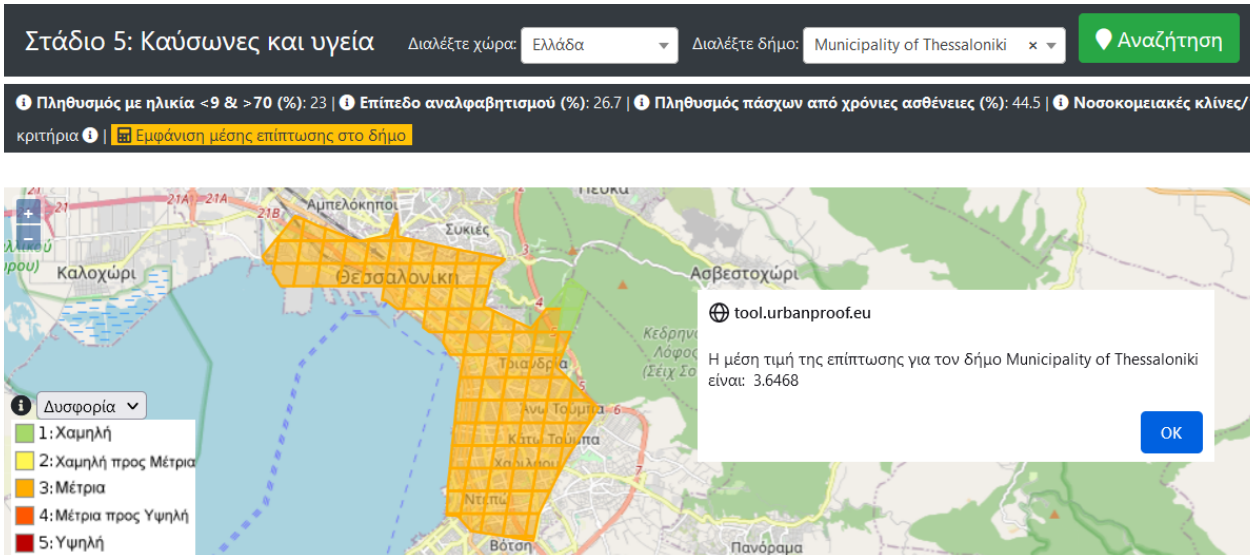

Figure 5 – The urban proof tool (https://tool.urbanproof.eu/editurbanproof/st5health.php) for heatwaves and health for the case of the municipality of Thessaloniki. The area is divided into 500x500 meters grid cells representing the human discomfort (green=low, yellow=low to moderate, orange=moderate, dark orange=moderate to high, red=high). The message in the white frame shows the average value of the human discomfort calculated by urbanproof tool. The results are identical before and after the introduction of green interventions into the tool.

b. Rome

The scenarios of urban green and urban park areas were applied to the city of Rome as well (**Figure 6**). The point effect of green interventions within neighbourhoods of the city (urban green) would be a decrease in Tapp by up to 1.8°C during the night, while a green park would affect the microclimate decreasing Tapp by up to 1.6°C. In addition, a steeper decrease is observed in Tapp between 15-21UTC (0.35°C/h instead of 0.26°C/h in case of urban park), which could facilitate the faster heat decongestion of the populations. During the day, both interventions are not able to cause any significant decrease in Tapp. However, similarly to Thessaloniki, urban park interventions may cause a slight decrease of Tapp by -0.3°C.

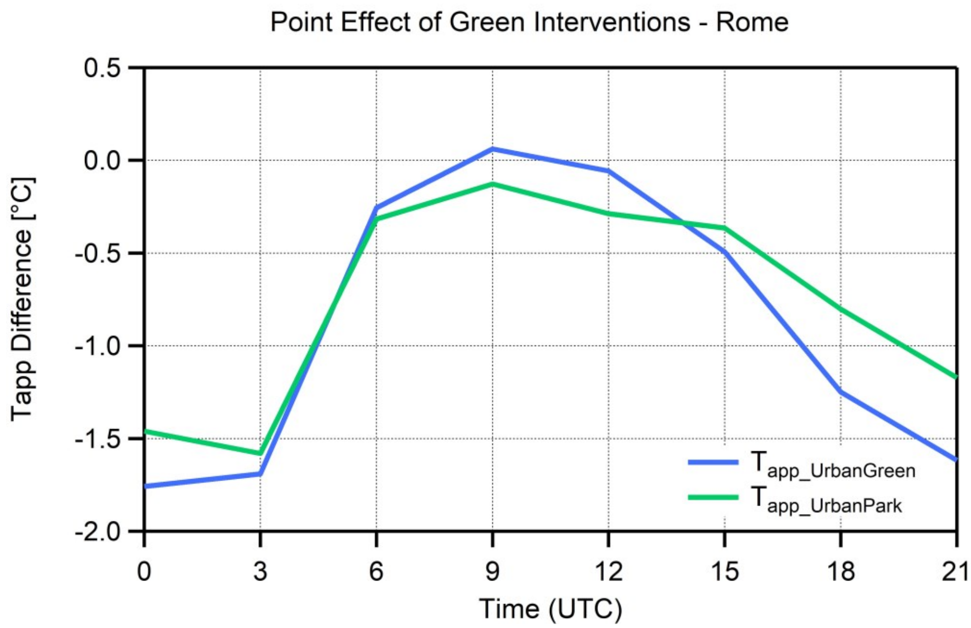

Figure 6 – Point effect of urban green (blue) and urban park (green) areas on Tapp for the city of Rome.

Next, we investigate various scenarios of altering albedo and emissivity (**Figure 7**) changing the land use and the materials used for the construction of roads and pavements (for further information read C7 report). It seems that the largest decrease (from the scenarios presented in this report) in Tapp (-2.8°C) can be achieved when decreasing both albedo and emissivity by 50% and 20% respectively. However, a Tapp decrease by 2°C can be achieved when decreasing emissivity by 20% without changing albedo. In contrast, in case of only decreasing albedo by 50%, the impact on Tapp is fairly lower (-0.81°C). On the other hand, an increase of emissivity by 5% followed by an albedo decrease <25% may lead to a slight Tapp increase by 0.1-0.2°C. Finally, although extreme scenarios of albedo/emissivity altering are shown, moderate and more realistic approaches (e.g., albedo and emissivity decrease of -5% to -10%) could still have a beneficial impact of reducing Tapp between -0.5°C to -1.5°C.

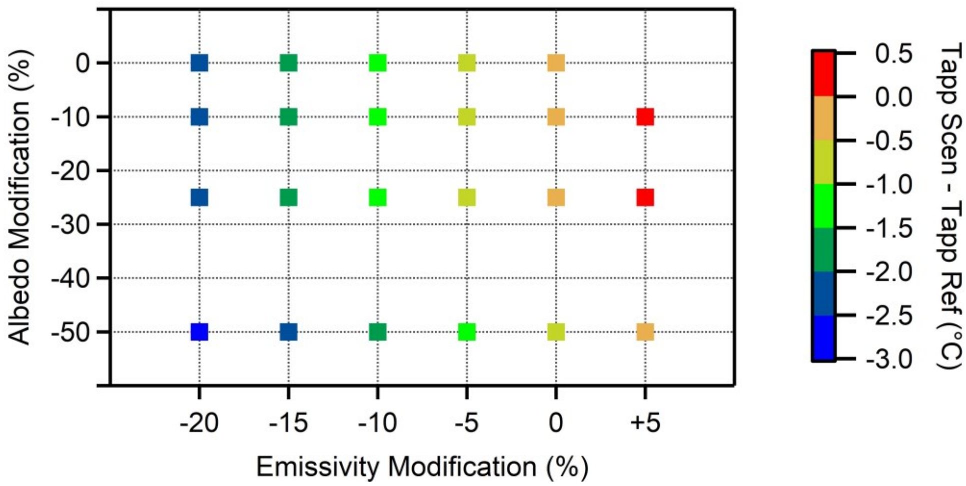

Figure 7 – Tapp difference between the current albedo-emissivity regime and the various scenarios of altering albedo-emissivity for the city of Rome.

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