🏆 *reviewed paper*

Building According to Climate Change

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1 ABSTRACT

Urban heat islands are a frequent phenomenon that significantly impacts liveability and human well-being. The ongoing research aims to provide an updated map of Tessin Canton's critical spatial and thematic areas in Switzerland. Furthermore, the objective is to investigate the level of performance of the current guidelines and provide indications to ensure a greater level of sustainability in the urban planning of cities.

In adapting to climate change, the Swiss Confederation established an action plan for 2020-2025 comprising 75 measures. This intersectoral coordination document provides the cantons and municipalities with practical actions for tackling climate change.

The research stems from a holistic view of the south of the Alps heat island phenomenon through an interdisciplinary and multiscalar approach. Therefore, the attention is on the trend of summer temperatures, particularly on days of heatwave. Furthermore, the study verifies the effects of the nature-based solutions adopted in the territory. In this way, it evaluates the impact of the measures in the action plan and the variables that most affect human well-being.

The study is developed in three consecutive phases based on the literature and the work carried out by the Federal Office for the Environment (UFAM). First, the available satellite images calculated the Land Surface Temperature (LST) and the perceived temperature (PET). Integrating these results with geospatial, demographic and settlement data has made it possible to identify the most sensitive areas of Tessin Canton.

In the next phase, the liveability in the heat islands was investigated. Various instruments (sensors, Climametro and thermal imaging camera) were used to analyse the climatic data and the data on the built environment in the urban area of Mendrisio, a city in the south.

In the third phase, the main aim was to verify the urban microclimate and provide valuable indications for the definition of a sustainable city. Therefore, the relationships between land use, urban typologies and abiotic nature were investigated.

The results of the ongoing research concern extending the heat islands of the Tessin Canton and evaluating the effects of the measures promoted by the UFAM. The next phase will allow for an in-depth study of the role of surface and groundwater in urban areas and valley floors. The aim is to provide further indications for implementing the sponge-city concept.

The ongoing study is possible thanks to the synergies between the University of Applied Sciences and Arts of Southern Switzerland and the Republic of Tessin Canton. The results obtained greatly help provide guidelines for sustainable territorial planning that is attentive to human well-being.

Keywords: climate change, abiotic natures, urban microclimate, heat islands, Tessin canton

2 ADAPTATION TO CLIMATE CHANGE IN SWITZERLAND

In Switzerland, the Confederation has a coordinated role in climate change adaptation. The action plan for 2020-2025[1] currently in force consists of 75 interdisciplinary measures, which are in continuity with the 2012 strategy and the 2014-2019 action plan. The goal is to coordinate the actions put in place and prepare the necessary to face the challenges of climate change.

Based on the work carried out by the UFAM[2] and the literature on heat islands, the ongoing project started in 2020. The objectives were defined by an interdisciplinary team of SUPSI and the Department of the Territory of Tessin Canton.

[1] "Adattamento ai cambiamenti climatici in Svizzera. Piano d'azione 2020–2025".
[2] Federal Office for the Environment.

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The project aims to map heat islands in Tessin Canton. In 2022, IPCC[3] defined the UHI[4] as "The relative warmth of a city compared with surrounding rural areas, associated with heat-trapping due to land use, the configuration and design of the built environment, including street layout and building size, the heat-absorbing properties of urban building materials, reduced ventilation, reduced greenery and water features, and domestic and industrial heat emissions generated directly from human activities".

The second objective is to investigate the perception of temperature within urban typologies. This aim allowed the study to obtain two other results. First, analyze the abiotic measures of the federal action plan in terms of performance. Furthermore, the study provided indications to improve the urban microclimate and gain greater sustainability in the urban planning of cities.

3 IDENTIFY HEAT ISLANDS

The research stems from a holistic view of heat island phenomenon through an interdisciplinary and multiscalar approach. Therefore, the attention is on the trend of summer temperatures, particularly on days of the heatwave.

The study is developed in three consecutive phases. During the first phase, the most problematic areas of the Tessin Canton were identified through the analysis of satellite data of the surface temperature. In addition to the impact of heat on the cantonal territory, it was essential to have information on the territory. Therefore, the study required information about the conformation of the territory to understand how it can absorb, reflect or reduce heat. At last, Canton's available territorial and demographic variables were needed to choose the relevant ones to identify the areas where the heat can produce the most significant impact on the territory and among the population.

3.1 The surface temperature and the perceived temperature

The first data analyzed were satellite data of the earth's surface temperature. The LST[5] is the temperature measured at the level of the earth's surface. According to Anderson et al., the LST is one of the most important parameters in the physical processes of surface energy and water balance at local through global scales.[6] Simplifying, it is not equivalent to the air temperature but to the temperature perceptible by touching a given surface.

The first step used an indicator that associates other variables with temperature to understand how environmental conditions affect people's well-being. It is the Physiologically Equivalent Temperature. According to Höppe, PET[7] is defined as the air temperature at which, in a typical indoor setting (without wind and solar radiation), the heat budget of the human body is balanced with the same core and skin temperature as under the complex outdoor conditions to be assessed.[8]

From a human bioclimatological point of view, it indicates the feeling of aphasia. The point was that people's thermal perception changes more rapidly than changes in air temperature. Matzarakis et al.[9] confirmed that the PET, expressed in °C, is a suitable indicator for the human-biometeorological evaluation of the thermal component of different climates.

After acquiring the LST values from satellite measurements[10], the maps of the perceived temperature were drawn up using a mathematical model based on the formula developed for the city of Dresden.[11] An initial check was carried out to validate the calculated PET. The case study was the Mendrisiotto Region, with the temperatures measured and the data acquired using the Climameter (see chapter 4.3).

[3] Intergovernmental Panel on Climate Change.
[4] Urban heat islands.
[5] Land Surface Temperature.
[6] "A thermal-based remote sensing technique for routine mapping of land-surface carbon, water and energy fluxes from field to regional scales".
[7] Physiologically Equivalent Temperature.
[8] "The physiological equivalent temperature - a universal index for the biometeorological assessment of the thermal environment".
[9] "Applications of a universal thermal index: physiological equivalent temperature".
[10] ECOSTRESS and Landsat 07.
[11] "Risiken beherrschen, Chancen nutzen. Die Region Dresden stellt sich dem Klimawandel".

Based on the available data, it was possible to produce three representations of the heat islands extension in Tessin Canton. The first map concerns the average extension of the heat islands on heat days with an average temperature above 25°. The second map identified the extent of heat islands during extreme weather events, such as in the summer of 2022, when the temperature exceeded 25° for two weeks. The maps underline that in addition to the more inhabited areas, there is an increase in temperature also on the valley sides.

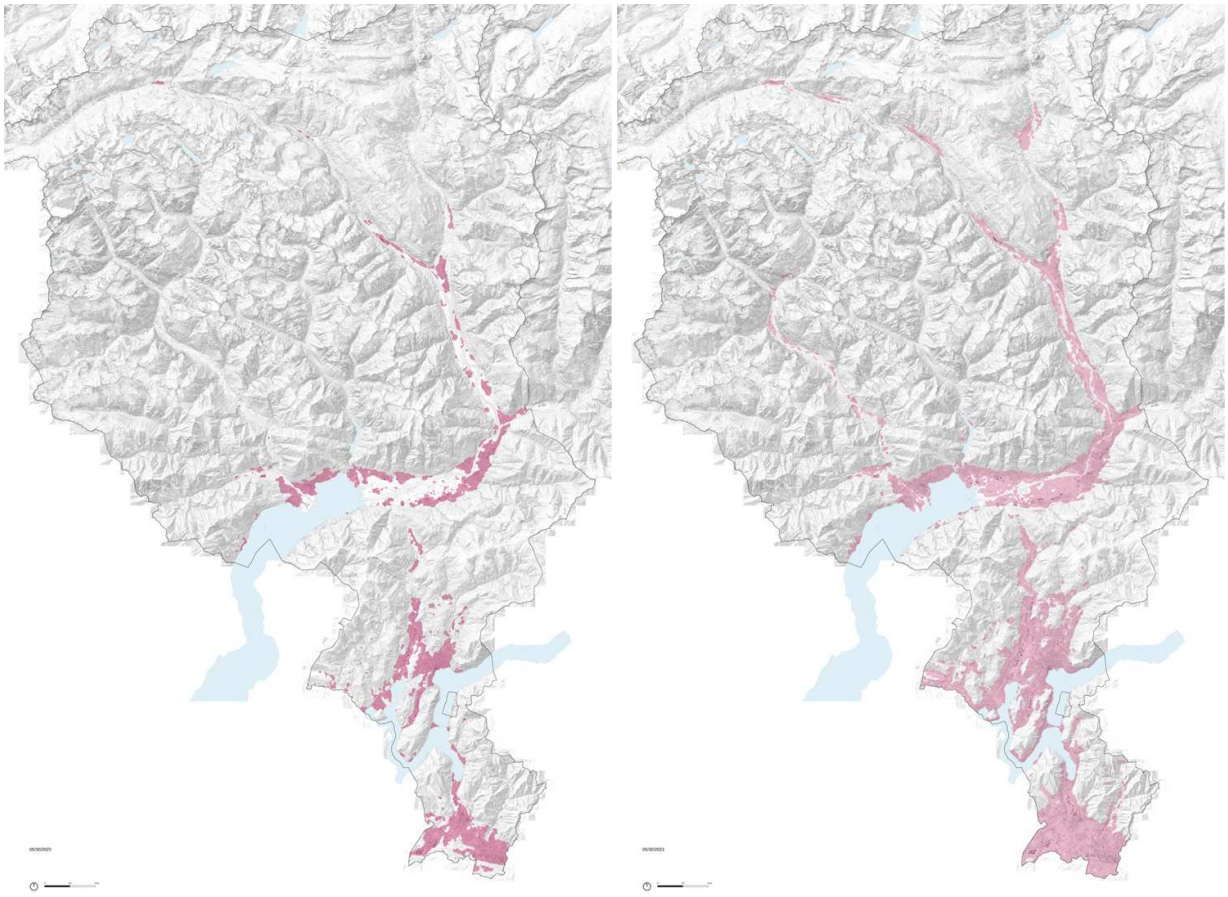

Fig. 1 (left): the average size of the heat islands. Elaborations by the authors (2023). Fig. 2 (right): the extension of the heat islands. Elaborations by the authors (2023).

Fig. 3: example of the sensitive and vulnerable areas of Tessin Canton. Elaborations by the authors (2023).

3.2 The sensitive and vulnerable areas

In addition to the maps already introduced, a further study was made to understand where high temperatures are a problem for the population of Tessin Canton. Sensitive areas are areas where the density of the resident

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population and workers exceeds 60 units/ha. This value is approximately equivalent to a utilization index[12] 0.5 that separates the typology of single-family houses with gardens from denser typologies. In addition, the study identified vulnerable areas where the density of children under five or people over 65 exceeds 20 inhabitants/ha. The analysis showed that heat islands often coincide with a high resident population density or employees.

4 LIVING IN URBAN HEAT ISLANDS

The elaborations in the first phase provided essential maps for understanding the urban heat island extension. Despite this, it took much work to indicate the abiotic nature measures to make urban microclimate more livable.

Therefore, three measurements examined the urban typologies and climatic elements determining well-being. The measurements concerned:

- the trend of the temperature and humidity of the air during 24h;
- the measurement of the surface temperatures with the thermal imaging camera;
- the evaluation of all the relevant data of the user in the space thanks to the Climameter.

The analyses were conducted in the Mendrisiotto region (focusing on Mendrisio, Stabio and Chiasso) during the summer of 2021.

4.1 Check the air temperature throughout the day

The first campaign verified different types of urban spaces on air temperature. The work aimed to compare spaces with similar characteristics in terms of construction and use but with different architectural and abiotic nature elements.

Bluetooth Data Loggers were installed in Mendrisio to record temperature and humidity trends. The loggers (Temperature range: -20° - +60°; Temperature accuracy: ± 0.5 °C; Humidity range: 0-99% RH; Humidity accuracy: ± 5% RH) were capable of registering data every 10 minutes and of archiving data for 100 days. The data were exported in CSV format via Bluetooth from up to 50m. A total of 24 sensors have been installed.

The comparison between measurements in the urban and rural areas was easy. The interpretation of the differences within the different urban typologies took more work. The analysis identifies that an irrigation system lowers the temperature by approx. 1° and that the shade lowers the area's temperatures by approx. 2°. However, these variations cannot describe the differences in terms of perception. The air temperature shows an average value that does not quantify the thermal stress a person is exposed to. Therefore, different measurement methods must be used to analyze other factors relevant to well-being within urban spaces.

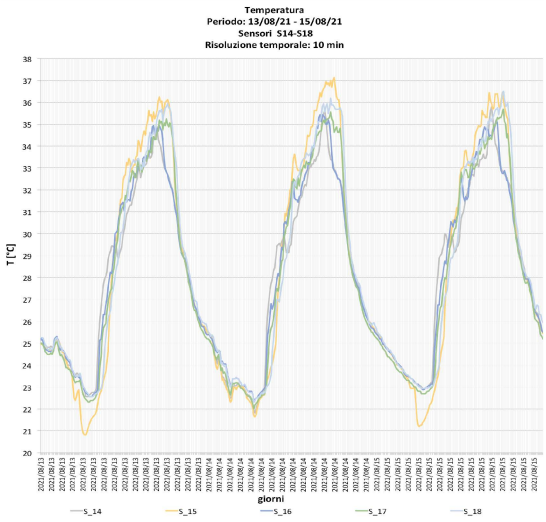

Fig. 4: the measurement campaign in Mendriso (CH) with Data Logger Bluetooth. Elaborations by the authors (2023).

[12] Relationship between the gross useful area built on a land and the area of the land.

4.2 Measure and display surface temperatures

A thermal imaging camera was used during the second survey. “In a limited sense thermal imiging is basically concerned wih converting images producted by the longer-wavelength thermal radiation emitte by these cooler bodies to visual wavelength images that we can see. In a broader sense the term thermal imaging can also apply to systems where no visual image is generated, but a thermal image is captured and processed entirely electronically to measure some specified parameter or detect the presence of some object.“[13]

The survey used the FLIR Lepton® camera with radiometric-capable solution that is smaller than a dime, fits inside a smartphone, and is one tenth the cost of traditional IR cameras. Using focal plane arrays of 80x60 active pixels, Lepton easily integrates into native mobile-devices and other electronics as an IR sensor or thermal imager. The radiometric Lepton captures accurate, calibrated, and noncontact temperature data in every image pixel.[14]

The following figure is an example of photos taken in the summer of 2021 in Mendrisio (CH).

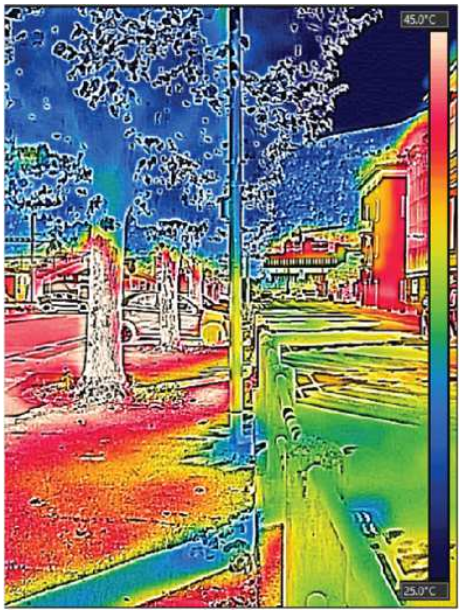

Fig. 5: the measurement campaign in Mendriso (CH) with FLIR Lepton® camera. Elaborations by the authors (2023).

4.3 Detecting and calculating perceived temperature

For the third campaign, the study applied the CityFeel method. It is developed by HEPIA[15] and includes a measurement protocol and the Climameter instrument. CityFeel measures the human perception of the immediate environment in terms of response to hygrothermics and air quality.[16]

The Climameter is a light and compact backpack that can be used on climatic trips anywhere in the city. It is composed of several sensors for ambient and radiant temperature in vertical and lateral directions, humidity and air movement (wind), solar radiation, and hemispherical visual environment (sight) from which some urban indicators are extracted (view of the sky). It records other parameters related to the composition of the air (CO_2, NO_x, Ozone, PM 2.5-10) and the acoustic situation. It also includes a platform, a GPS and a data logging system.

The data collected by the sensors feed a model of the thermal equilibrium of the human body to evaluate PET. Other common indicators of comfort or stress are also calculated, such as PMV - Predicted Mean Vote, UTCI – Universal Thermal Climate Index, HUMIDEX - Humidity Index, and WBGT – Wet Bulb Globe Temperature.

[13] “Thermal Imaging Cameras: Characteristics and Performance.”
[14] https://www.flir.com/products/lepton/
[15] Haute École du Paysage, d’ingénierie et D’architecture De Genève.
[16] “CityFeel – micro climate monitoring for climate mitigation and urban design”.

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The µCM-Viewer facilitates the observation and interpretation of the collected data using a graphical interface, making it possible to reproduce and analyze ex post the climatic paths performed in an almost immersive way.

The instrument was used for surveys in Mendrisio, Stabio and Chiasso during the summer of 2021. Around 20 routes were carried out at different times (morning, afternoon, and evening), each relief from one to two and a half hours. The planned routes were close to the 24 Bluetooth Data Loggers, close to the Meteoswiss measuring stations[17] in Stabio and close to the OASI[18] measuring stations in Mendrisio to compare the data. Furthermore, the main points of interest for the population were considered, such as hospitals, retirement homes, universities, railway stations, historical centres, industrial areas and open squares.

This campaign combined the factors mentioned in the first two campaigns and was crucial to represent the human experience.

Fig. 6: the measurement campaign in Mendrisio (CH) with the HEPIA Climameter. Elaborations by the authors (2023).

5 RECOGNIZING THE POTENTIAL OF URBAN TYPOLOGIES

The third phase aimed to verify the effects of the natural solutions adopted in the territory according to the analyses developed by Kleerekoper[19] about urban design and the indications in "Reducing Urban Heat Islands: Compendium of Strategies"[20] regarding the importance of trees on streets and parking lots. Specifically, the present study evaluated the impact of measures, including the federal action plan and the variables that most impact human well-being. Therefore, the relationships between land use, urban typologies and abiotic nature were investigated.

5.1 The retention and reflection of materials

Construction materials with different heat retention or heat reflection were considered. Analyzes have underlined that the most pleasant place in Mendrisio in the summer is still the historic centre. Even on hot summer afternoons, temperatures remain below the stress limit. The combination of shade with surface materials that balance the temperature throughout the day allows the cool of the night to be transported into the day.

Regarding the colours of the facades, light colours reflect the light better and heat up less. Therefore, making surfaces lighter usually reduces heat build-up. Nevertheless, light colours can increase PET if the reflective effect of white makes the situation in front of the facades less pleasant.

[17] The automatic network SwissMetNet from MeteoSwiss.
[18] The network of monitoring stations of the Tessin Canton Environmental Observatory.
[19] "Urban measures for hot weather conditions in a temperate climate condition: A review study"
[20] "Reducing Urban Heat Islands: Compendium of Strategies"

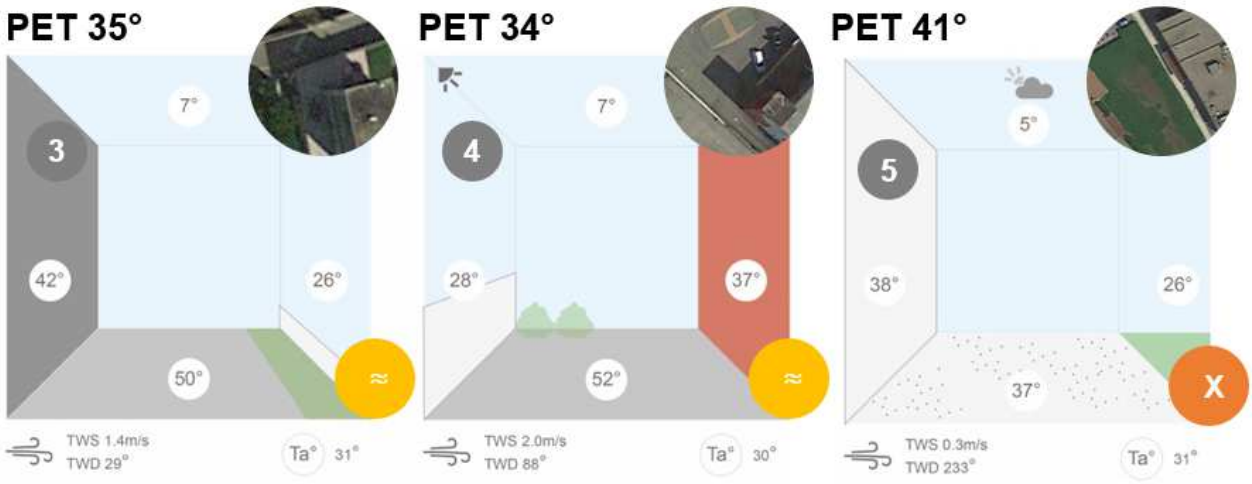

Fig. 7: elaborations to investigate the effect of the materials and colors of the facades. Elaborations by the authors (2023).

5.2 The waterproof or vegetable flooring

Different ground, such as asphalt, gravel, grass or reinforced grass for parking, are typical of the study area.

In the industrial area of Stabio, the difference between partially impermeable surfaces with tree-lined streets and asphalted streets or an impermeable street situation without elements giving shade was analyzed. The comparison of the collected data underlines that the introduction of single green elements contributes little to urban microclimate for people's well-being.

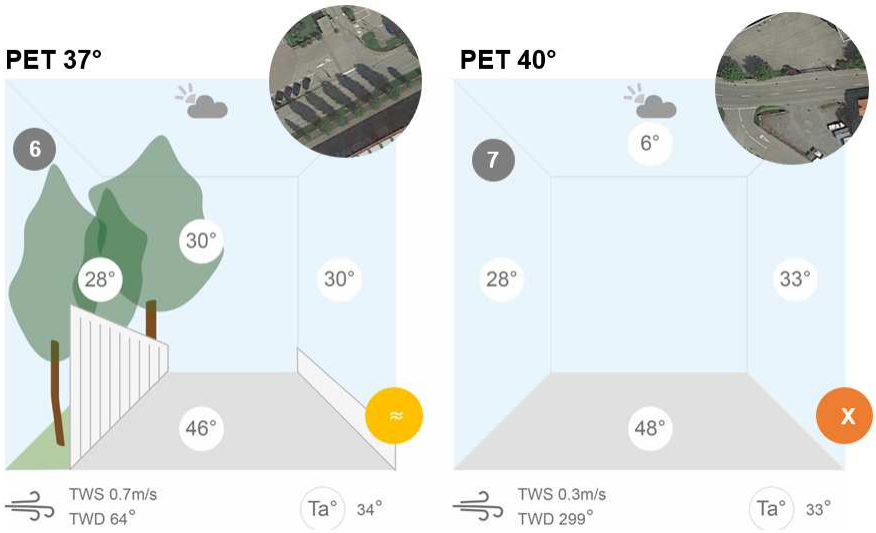

Fig. 8: elaborations to investigate the introduction of individual green elements. Elaborations by the authors (2023).

Combining the measures improves the situation for the user. Mendrisio's case study, for example, compared two car parks. The first combines trees with a permeable floor. The second case is entirely paved without mitigation measures. Data analysis of a summer heat day PET differs by almost 10 degrees between these two situations.

At last, a combination of elements is needed to improve the situation. Furthermore, the attention should certainly be paid to water retention. Vegetated soil conserves humidity and contributes to a pleasant climate, so ideally, the city becomes a Sponge City. According to the World Future Council, Sponge City indicates a particular type of city that does not act like an impermeable system not allowing any water to filter through the ground, but, more like a sponge, actually absorbs the rain water, which is then naturally filtered by the soil and allowed to reach into the urban aquifers. This allows for the extraction of water from the ground through urban or peri-urban wells. This water can be easily treated and used for the city water supply.[21]

[21] "Sponge Cities: What is it all about?"

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5.3 The shade or exposure to solar and reflected radiation

The sky is usually pleasantly cool, and its surface temperature is between 5-7 degrees, higher with cloud cover. Thus, even in summer, people feel the cooling effect of the sky when they are outside. The sun's radiation compensates for this effect wherever shade is not.

Exposure to high temperatures is also influenced by the buildings' shade. For example, the situation between the sun and shade of the new SUPSI building in Mendrisio is lowered by over 10° PET despite the same external arrangement. This means it is comfortable during sunny days in the winter but becomes almost unlivable in the summer.

Finally, the data has shown that the temperature of gravel squares or dry green areas does not differ much from asphalted squares. The introduction of trees brings PET closer to air temperature. Therefore, the data is below the heat stress limit.

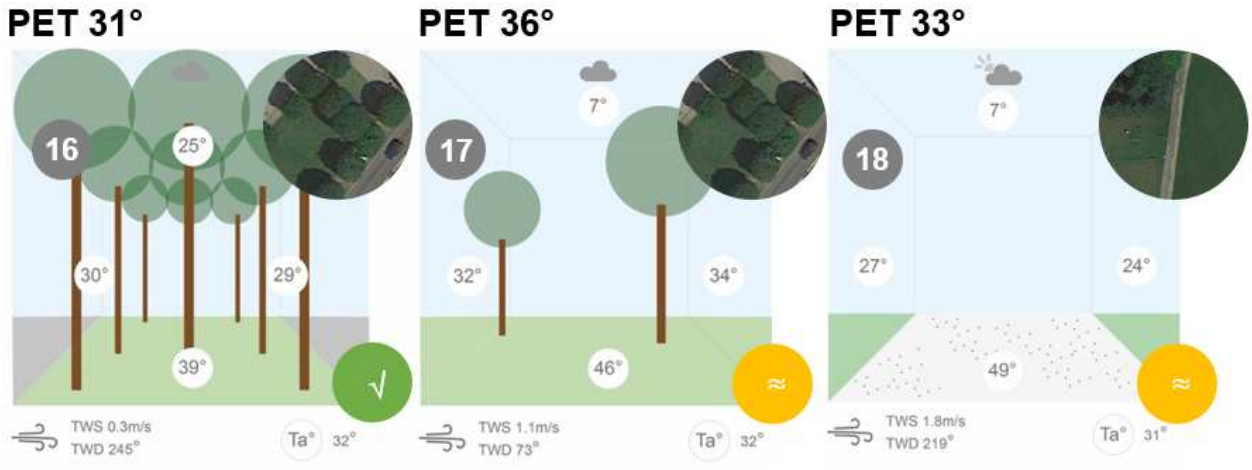

Fig. 9: elaborations to investigate the effect of shadow in public spaces. Elaborations by the authors (2023).

5.4 The design or not of the vegetation on the walls

Greening roofs and walls can mitigate the overheating effect. Plants cool the air by evaporating water and radiating less heat. A green facade or an intensive green roof thus also contributes to an acceptable climate in the public space.

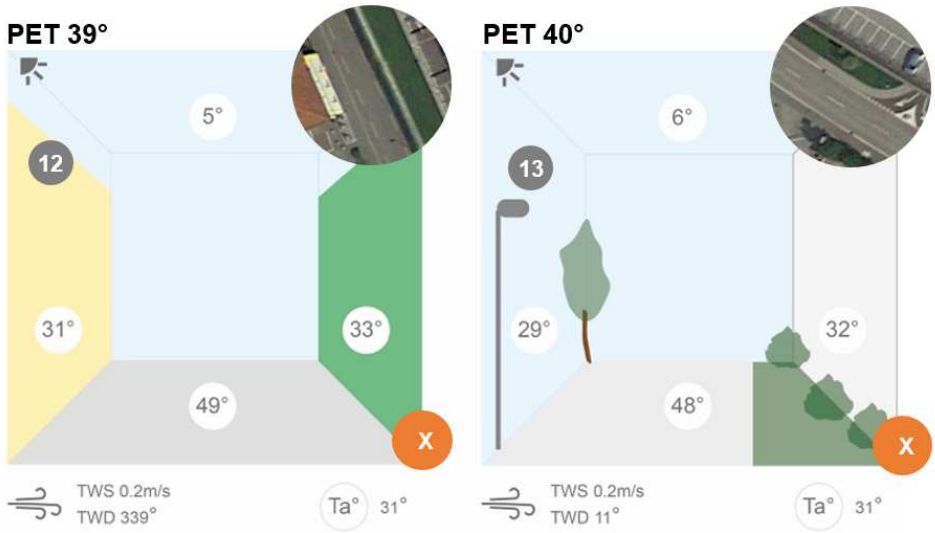

Fig. 10: elaborations to investigate the effect of the greening of the walls. Elaborations by the authors (2023).

From these considerations, three situations in Mendrisio were analyzed during an August day with a clear sky and 31-32° degrees. The first case is a 20th-century street with buildings alternating with tree-lined gardens in front of a large park with centenary trees. Along the same road, the gardens are either converted to waterproof outdoor parking or occupied by a semi-underground garage bordering the road. The third case considered green walls. The analyzed data showed that greening private gardens without measures in the

road space lowers the temperature, but not below the necessary value. The green roof does not bring significant benefits to the public space. A similar effect is the case of green walls: the data analyzed do not show a significant contribution to well-being. Therefore, single greening interventions in a predominantly impermeable and built space exposed to the sun do not significantly contribute.

6 A NEW ATTENTION TO THE QUALITY OF PUBLIC SPACES

The ongoing study shows that in many localities in Tessin when an air temperature of 30° is reached or exceeded, people are already exposed to severe heat stress of over 38° PET. Therefore, reductions in the perceived temperature of approximately 10° are necessary to bring the situation back within tolerable limits. As described in the paper, applying single measures has limited effectiveness. In the best cases, they reduce a few degrees to a maximum of 5°. Only public spaces that combine several measures to reduce heat islands manage to achieve the goal. These reflections will be fundamental for envisaging measures and interventions in the cities of the valley floor but also for small or medium-sized urban centres, located in the valleys or in the mountains. Planners need to pay more attention to thermal comfort conditions in urban typologies, and interventions are also needed to limit overheating phenomena through ventilation or natural cooling measures of the external spaces. Therefore, more than a cosmetic greening of the existing city is required. A new approach to the design of urban spaces will be necessary so that they are also pleasant to live in as a function of climate change.

The research is still in progress. The deadline is expected in 2025. During 2023 the focus is on identifying the contribution of night cooling, on the open-source dissemination of the maps created and on the involvement of the municipalities to introduce the study results. At the moment, the phenomenon of heat islands must be addressed according to a holistic vision that includes the processing and interpretation of different types of data at different scales of intervention.

The importance of involving the population and local authorities is undeniable for the future. The focus of reflection must be the well-being of citizens in adapting to climate change.

7 ACKNOWLEDGEMENT

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