Urban trees and green spaces for climate-resilient cities in Switzerland

Project report, December 2022

Authors: Myke Koopmans and Edouard Davin (Wyss Academy for Nature at the University of Bern)

Key insights

- Green areas and trees reduce surface temperature during heatwaves in all Swiss cities analyzed
- Specific urban features such as train stations, railway tracks, artificial turf sport fields, and industrial areas often lead to heat hotspots in most cities
- Combining temperature remote sensing and socio-economic data, we will generate risk maps at city-scale providing guidance towards practical implementation of regreening strategies

Objectives and methods

In this project, we aim to assess the effectiveness of trees and/or green spaces as a heat mitigation measure in Swiss cities. We focus our analysis on three heat wave summers (2015, 2018 and 2019) and on the cities of Basel, Bern, Geneva, Lausanne, and Zürich. After examining the relationship between urban vegetation and temperature, we map heat hot spots within cities and analyze their underlying causes.

We also aim to provide policy relevant recommendations in terms of possible adaptation strategies to heat in cities. In this respect, we took a socio-economic approach aiming at identifying the vulnerability of city neighborhoods to heat based on physical but also socio-economic factors. Several studies have identified a link between temperature patterns and socio-economic factors in urbanized areas (Buyantuyev and Wu, 2010; Chakraborty *et al.*, 2019; Hoffman, Shandas and Pendleton, 2020; McDonald *et al.*, 2021). In addition, in people from lower socio-economic environments are in general more vulnerable to the effects of urban heat and have less resources to mitigate its effects (Reid *et al.*, 2009; Gronlund, 2014).

A combination of physical and socio-economic data has been used in this project as a basis of spatial and statistical analysis.

- The temperature data has been based on the Land Surface Temperature (LST), derived from Landsat 8 satellite data. The method of Parastatidis *et al.* (2017) has been applied for the LST calculations. The heat waves of the 2015, 2018 and 2019 summers were used for the analysis.

- Landsat 8 data has been used to derive the Normalized Difference Vegetation Index (NDVI), an index to detect alive green vegetation.
- Infrastructural information on buildings, waterways and municipal neighborhood boundaries was based on the data of Swiss Map Vector 10 provided by the Federal Office of Topography swisstopo.
- The locations of trees were based on municipal tree registries (when available) and tree data of WSL (Waser *et al.*, 2021).
- The socio-economic data is on neighborhood scale. The data was gathered from the statistical offices of the relevant cities. Depending on the data availability this contained information regarding population density, income, wealth, age, welfare, education level, housing size, jobs, unemployment, etc.
- The areal imagery was accessed via the federal geoportal; geo.admin.ch

Initial results

In order to evaluate the cooling effect of green spaces within cities a comparison was made between areas with and without trees. In addition, the effect of NDVI on LST was assessed. The comparison of locations with and without trees showed that on average the location with trees are cooler than without trees, the magnitude of this difference varies depending on neighborhoods. An example of the detected differences in temperature between areas with and without trees is shown in Figure 1. The assessment of LST and NDVI resulted in a clear link between temperature and vegetation (see Appendix I). Areas with higher NDVI had generally lower LST values, indicating a positive effect of green spaces on temperature reduction within city neighborhoods.

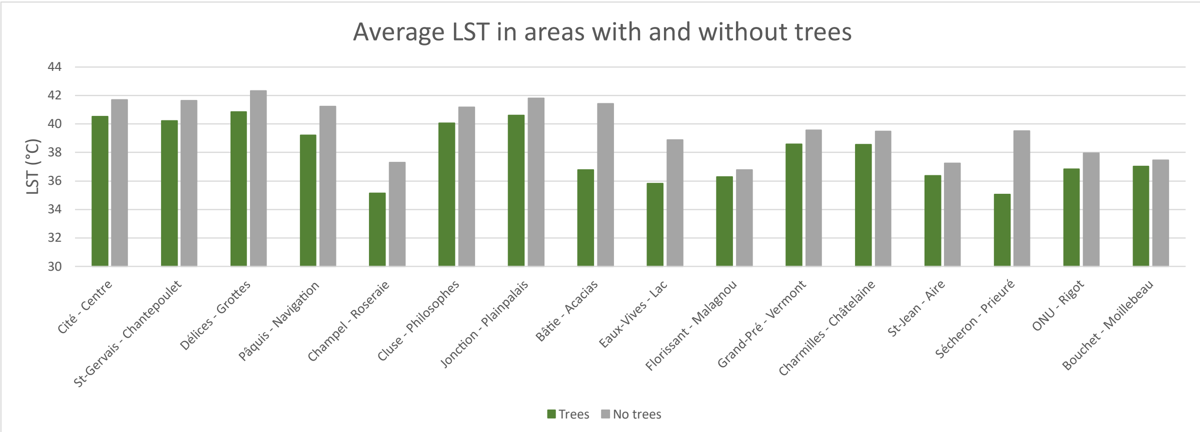

FIGURE 1 THE DIFFERENCE BETWEEN AREAS WITH AND WITHOUT TREES IN THE CITY OF GENEVA PER NEIGHBORHOOD

The identification of the main hotspots within a city resulted in a better understanding of the factors contributing to urban heat. The type of hotspots which could be identified within the cities had overlapping characteristics, namely; train stations, railway tracks, artificial turf sport fields, and industrial areas. The maps of Basel, Bern, Geneva, Lausanne and Zürich can be seen in Appendix II. These are locations with high human and economic activity.

The neighborhoods in the city center tend to be the warmer areas. Even though the number of residence in these neighborhoods are relatively low, these are areas where a high number of people can be found during the day.

The link between temperature anomalies and socio-economic factors was not uniform across cities, indicating city-specific dynamics. While some socio-economic factors correlate with LST, most did not give strong relationships. This could have been a result of the limited sample size; the number of neighborhoods of a city. A clear link which could be observed was a correlation between building density and LST. When looking for correlations within a city, for Geneva a correlation between social welfare recipients and LST was detected as well as the number of jobs in the neighborhood and LST.

However, a trend between temperature and socio-economic factors can be visually observed in specific areas; e.g. the neighborhood of Saint-Gervais - Chantepoulet in Geneva which has above average temperatures, a higher percentage of social welfare precipitants, lower income and a high number of jobs in the area. Appendix III gives an example of this spatial distribution of the city of Geneva. In a next step, risk maps will be developed (see 'Next steps in the project'). These maps will be based on the exposure to high temperatures and vulnerability criteria based on the socio-economic factors.

Workshops

On December 2nd 2022 a workshop has been organized to bring together Swiss scientists working on urban heat related projects. The aim of this workshop was to connect and exchange knowledge. During this workshops possible synergies and potential collaborations have been discussed. Gained insights of previous experiences of translating science towards policy has also been discussed. One key action point was to strengthen data and knowledge exchange between the various groups working around this topic.

As a follow-up a policy workshop will be organized for first half of 2023 with a view toward translating knowledge into action.

Next steps in the project:

- Urban heat risk maps will be developed based on the physical and socio-economic factors in order to:
    - Identify areas with high risk
    - Provide a visual overview on priority areas needing particular attention
    - Provide guidance towards practical implementation of regreening strategies

- Policy workshop, with a focus on:
    - Exchange of experiences and knowledge between different municipalities and administrative levels
    - What scientific evidence is still missing and what are the research needs to close this knowledge gap?
    - What scientific insights (e.g. from the project) could already be translated into action and could be the basis for a possible pilot project?

- Peer-reviewed publication
    - A scientific publication will be submitted until May 2023 in order to share the results and insights of this project

References:

Buyantuyev, A. and Wu, J. (2010) ‘Urban heat islands and landscape heterogeneity: linking spatiotemporal variations in surface temperatures to land-cover and socioeconomic patterns’, *Landscape Ecology*, 25(1), pp. 17–33. Available at: https://doi.org/10.1007/s10980-009-9402-4.

Chakraborty, T. *et al.* (2019) ‘Disproportionately higher exposure to urban heat in lower-income neighborhoods: a multi-city perspective’, *Environmental Research Letters*, 14(10), p. 105003. Available at: https://doi.org/10.1088/1748-9326/ab3b99.

Gronlund, C.J. (2014) ‘Racial and Socioeconomic Disparities in Heat-Related Health Effects and Their Mechanisms: a Review’, *Current Epidemiology Reports*, 1(3), pp. 165–173. Available at: https://doi.org/10.1007/s40471-014-0014-4.

Hoffman, J.S., Shandas, V. and Pendleton, N. (2020) ‘The Effects of Historical Housing Policies on Resident Exposure to Intra-Urban Heat: A Study of 108 US Urban Areas’, *Climate*, 8(1), p. 12. Available at: https://doi.org/10.3390/cli8010012.

McDonald, R.I. *et al.* (2021) ‘The tree cover and temperature disparity in US urbanized areas: Quantifying the association with income across 5,723 communities’, *PLOS ONE*. Edited by K.K. Singh, 16(4), p. e0249715. Available at: https://doi.org/10.1371/journal.pone.0249715.

Parastatidis, D. *et al.* (2017) ‘Online Global Land Surface Temperature Estimation from Landsat’, *Remote Sensing*, 9(12), p. 1208. Available at: https://doi.org/10.3390/rs9121208.

Reid, C.E. *et al.* (2009) ‘Mapping Community Determinants of Heat Vulnerability’, *Environmental Health Perspectives*, 117(11), pp. 1730–1736. Available at: https://doi.org/10.1289/ehp.0900683.

Waser, L.T. *et al.* (2021) ‘Mapping dominant leaf type based on combined Sentinel-1/-2 data – Challenges for mountainous countries’, *ISPRS Journal of Photogrammetry and Remote Sensing*, 180, pp. 209–226. Available at: https://doi.org/10.1016/j.isprsjprs.2021.08.017.

Appendix I

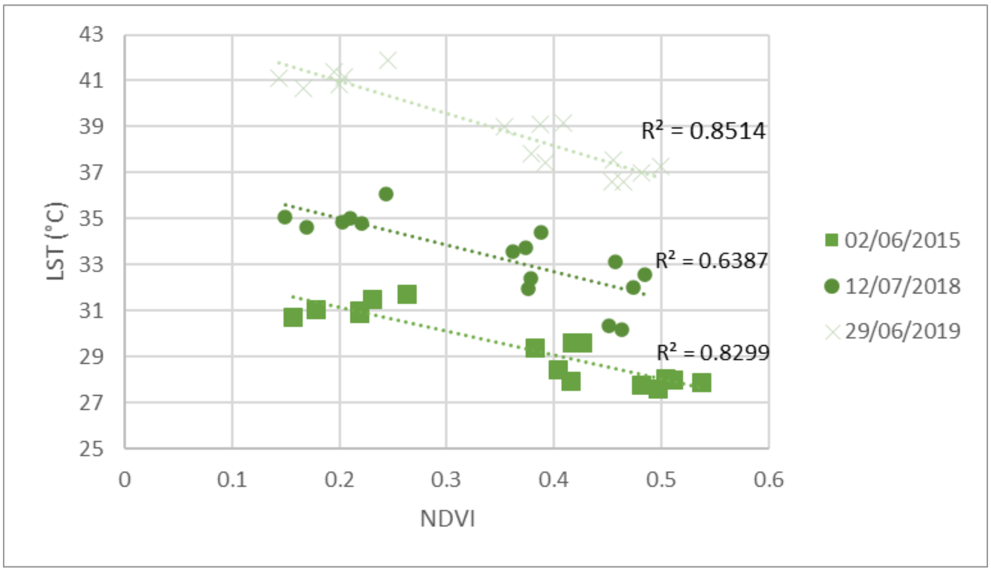

FIGURE 2 THE COMPARISON OF AVERAGE LST AND NDVI PER NEIGHBORHOOD OF THE CITY OF GENEVA.

Appendix II

Basel

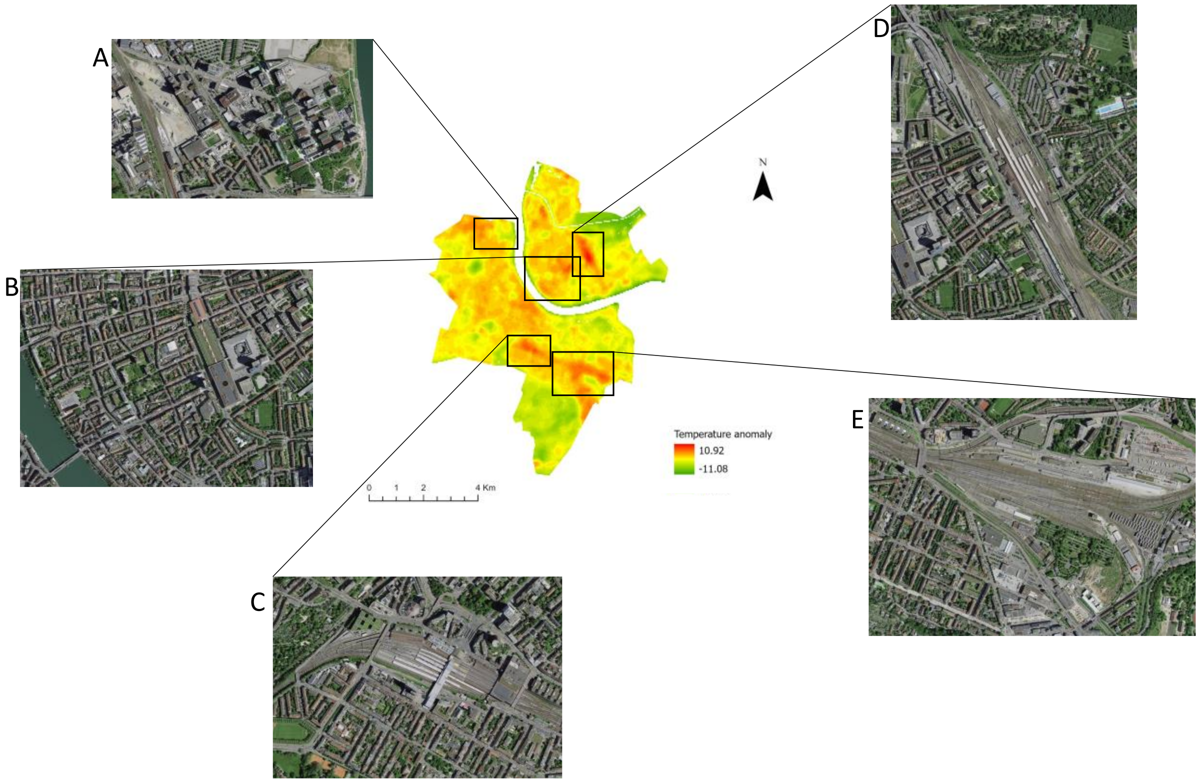

FIGURE 3 TEMPERATURE ANOMALIES IN THE CITY OF BASEL. WITH; A. INDUSTRIAL AREA WITH HIGH NUMBER OF WAREHOUSES, B. CITY CENTER OF BASEL WITH INCREASED LST VALUES AROUND THE MESSEPLATZ, C. BASEL TRAIN STATION, D. BASEL BAD TRAIN STATION, E. RAIL DEPOT.

Bern

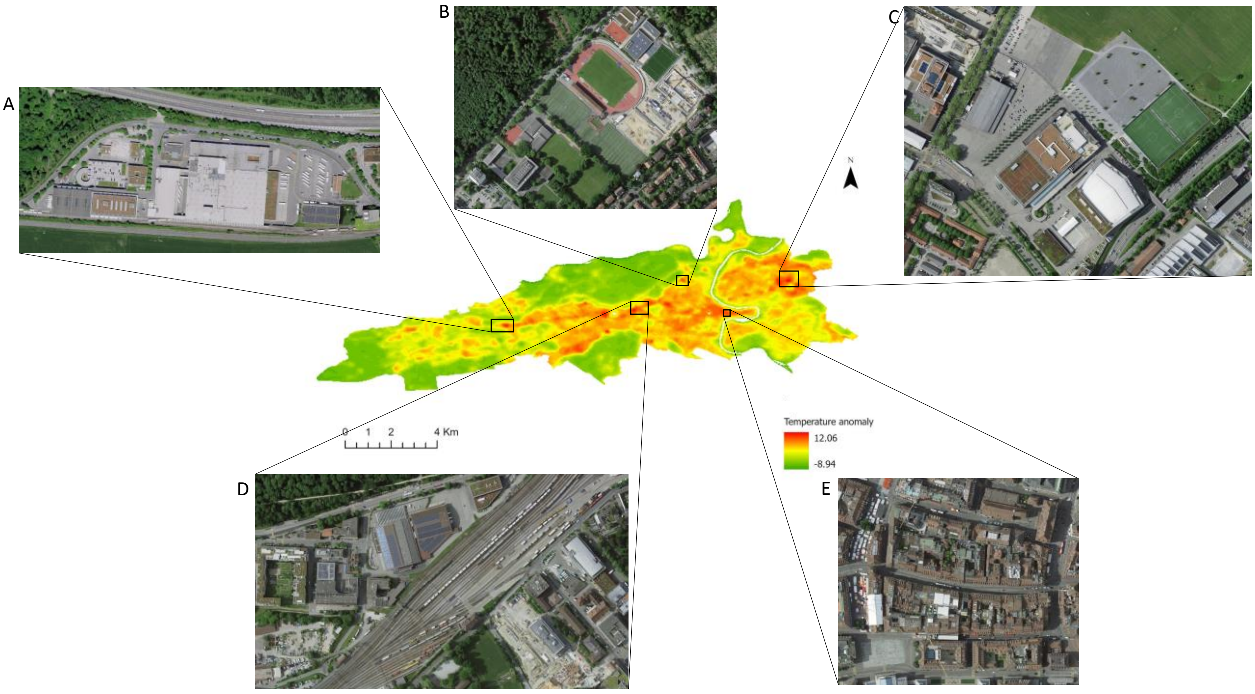

FIGURE 4 TEMPERATURE ANOMALIES IN THE CITY OF BERN. WITH; A. INDUSTRIAL AREA WITH HIGH NUMBER OF WAREHOUSES, B. ARTIFICIAL SPORT FIELDS AT SPORTPLATZ NEUFELD, C. BERN EXPO AND ARTIFICIAL SPORT FIELDS OF SPORTPLATZ ALLMEND, D. RAILWAY TRACKS NEAR WEYERMANNSHAUS STATION, E. HIGH BUILDING DENSITY OF THE CITY CENTER NEAR BÄRENPLATZ.

Geneva

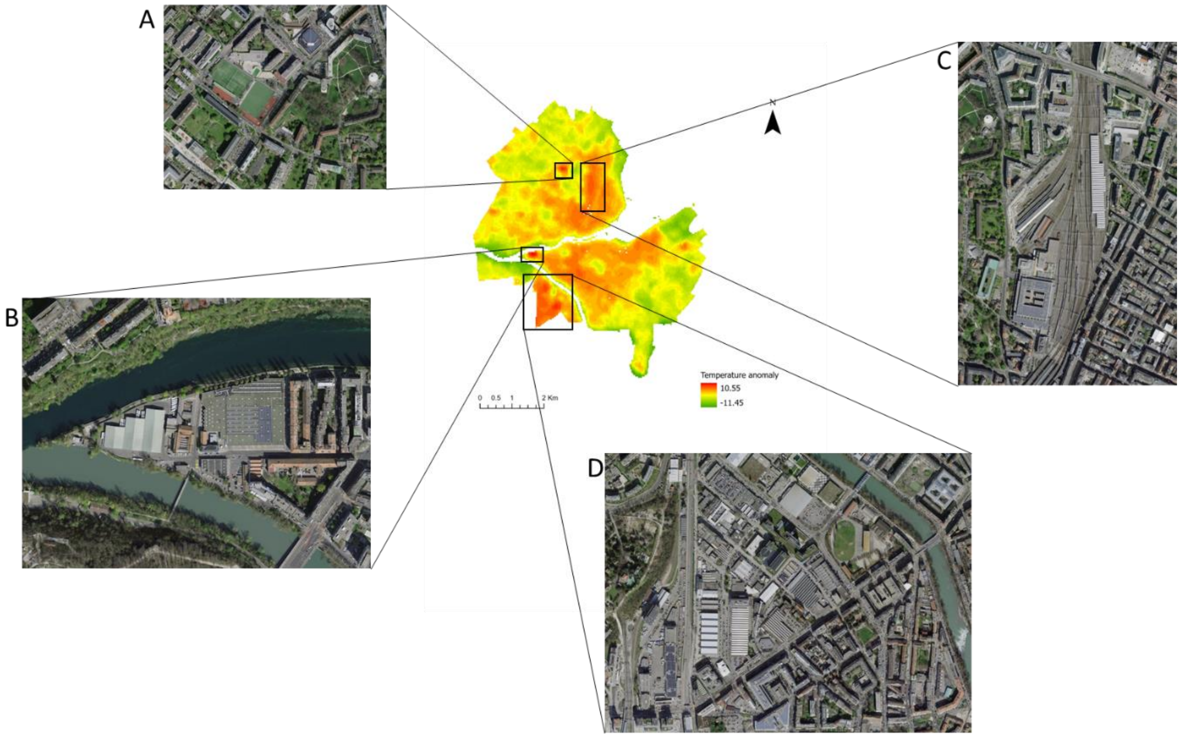

FIGURE 5 TEMPERATURE ANOMALIES IN THE CITY OF GENEVA. WITH; A. ARTIFICIAL SPORT FIELDS AT VAREMBÉ SPORTS CENTER, B. INDUSTRIAL AREA WITH LARGE WAREHOUSES, C. RAILWAY TRACKS NEAR GENEVA TRAIN STATION , D. INDUSTRIAL AREA WITH LARGE DENSITY OF WAREHOUSES.

Lausanne

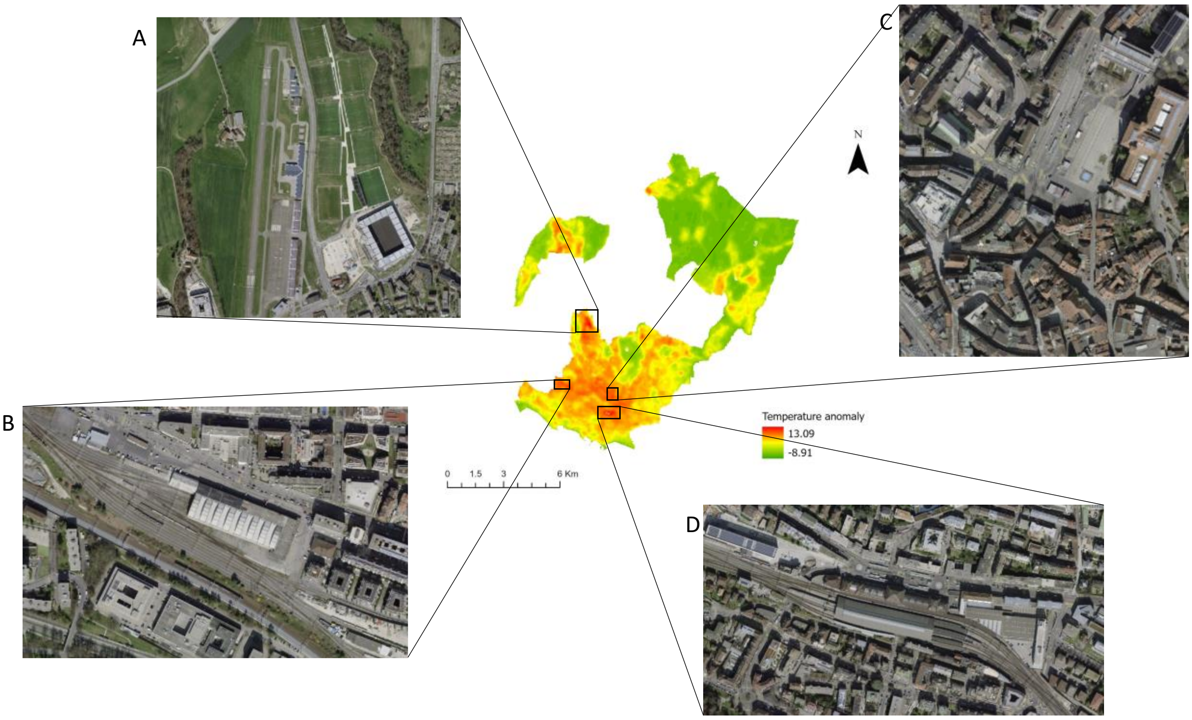

FIGURE 6 TEMPERATURE ANOMALIES IN THE CITY OF LAUSANNE. WITH; A. ARTIFICIAL SPORT FIELDS AT LA TUILIÈRE SPORT COMPLEX AND LAUSANNE AIRPORT , B. LAUSANNE-SÉBEILLON TRAIN STATION, C. HIGH BUILDING DENSITY AND LOW VEGETATION PRESENCE NEAR PLACE DE LA RIPONNE, D. LAUSANNE TRAIN STATION.

Zürich

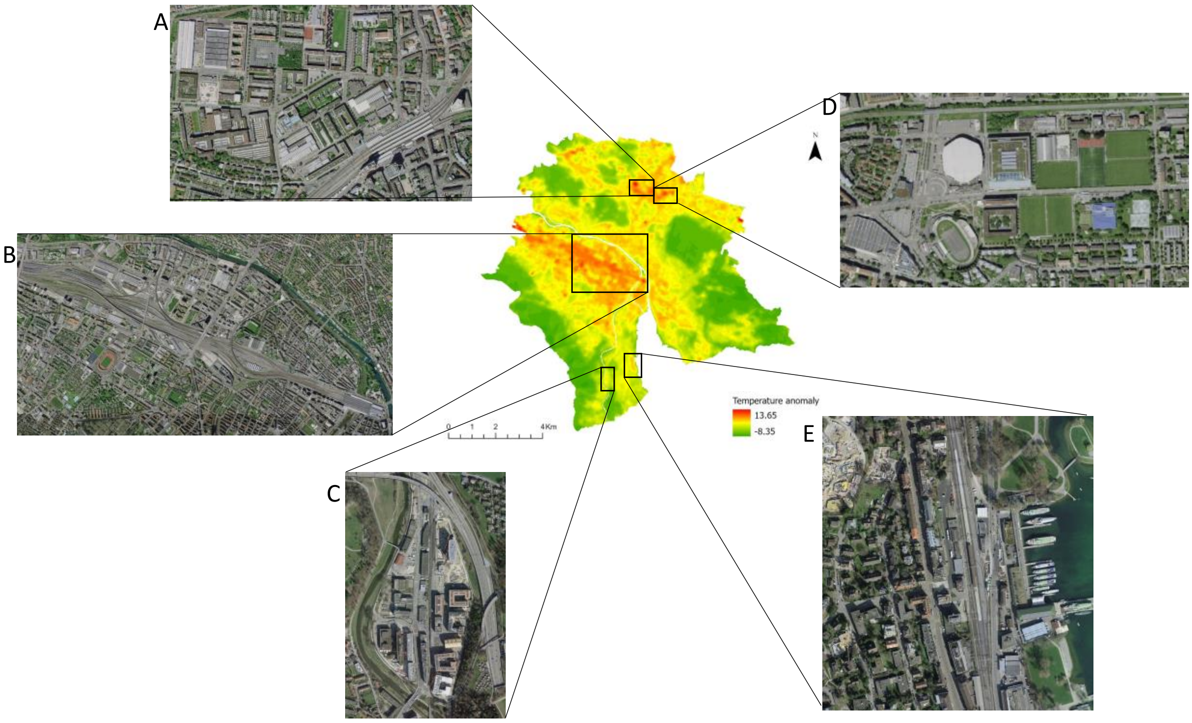

FIGURE 7 TEMPERATURE ANOMALIES IN THE CITY OF ZÜRICH. WITH; A. INDUSTRIAL AREA WITH LARGE DENSITY OF WAREHOUSES, B. THE RAILWAY TRACKS RELATED TO ZÜRICH HAUPTBAHNHOF, ZÜRICH HARDBRÜCKE AND ZÜRICH ALTSTETTEN, C. NEWLY DEVELOPED GREEN CITY, D. THE AREA AROUND HALLENSTADION AND MESSE ZURICH IN ADDITION TO THE ARTIFICIAL TURF FIELDS AT THE SPORTANLAGE NEUDORF, E. ZÜRICH WOLLISHOFEN TRAIN STATION

Appendix III

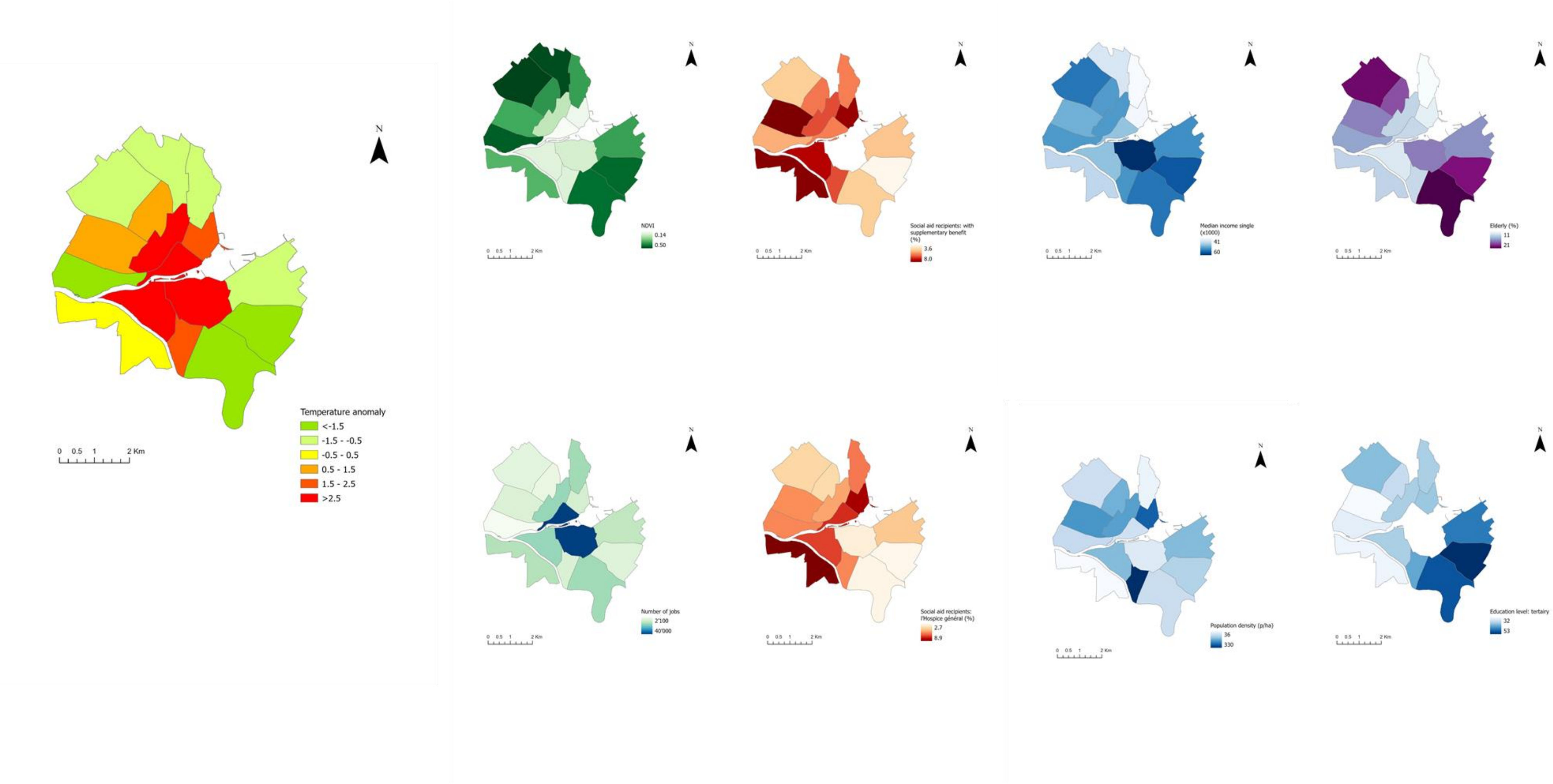

FIGURE 8 A SPATIAL OVERVIEW OF USED FACTORS FOR THE CITY OF GENEVA