DESIGN PROJECT - SIE 2024

IMPACTS OF DEVELOPMENT PROJECTS ON URBAN HEAT ISLANDS

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OBJECTIVES

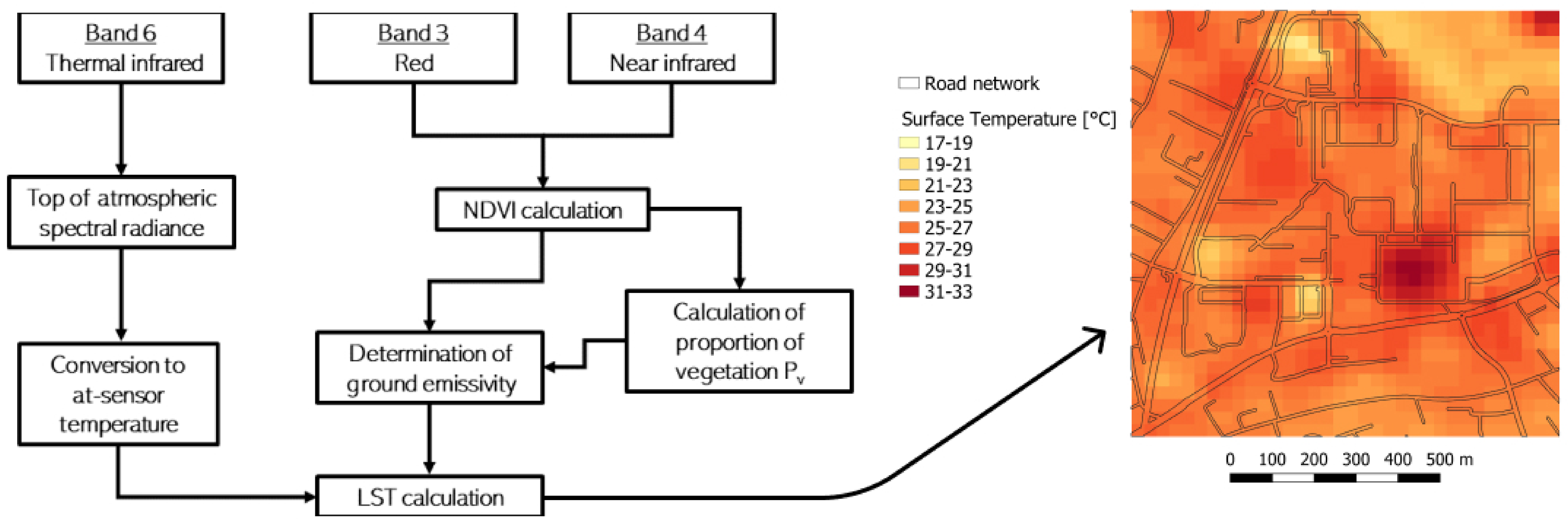
This project aims to provide urban planners and professionals in the field with a simple methodology to evaluate the surface temperatures in an urban environment and to model the impact of development scenarios and mitigation strategies to improve the quality of life for locals.

SURFACE TEMPERATURE OBSERVATION

Surface temperatures can be computed from images taken in the thermal infrared region of the electromagnetic spectrum (8 to 15 µm) through remote sensing techniques such as airborne or satellite imagery.

THERMAL IMAGING - SATELLITE IMAGERY

This methodology is suited to the data provided by the Enhanced Thematic Mapper Plus sensor from the Landsat 7 mission by NASA. It calculates the emissivity-corrected land surface temperature.



(Avdan and Jovanovska, 2016)

\+
- direct observation
- high accuracy
- world coverage
- data availability

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- fixed transit time due to sun-synchronous orbit

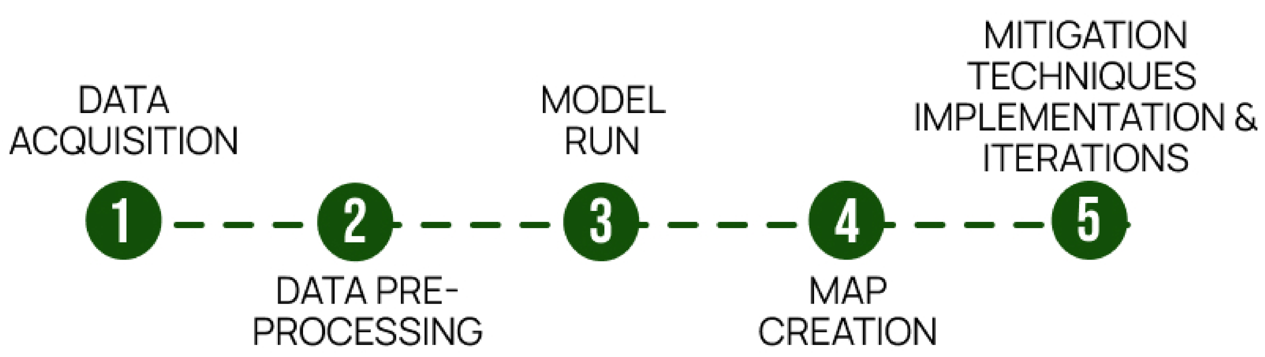
SURFACE TEMPERATURE MODELING

The numerical models presented here calculate the surface temperature by solving the surface energy balance. The equation relates the variation in surface heat storage with the net radiation, sensible heat, latent heat and ground heat fluxes.

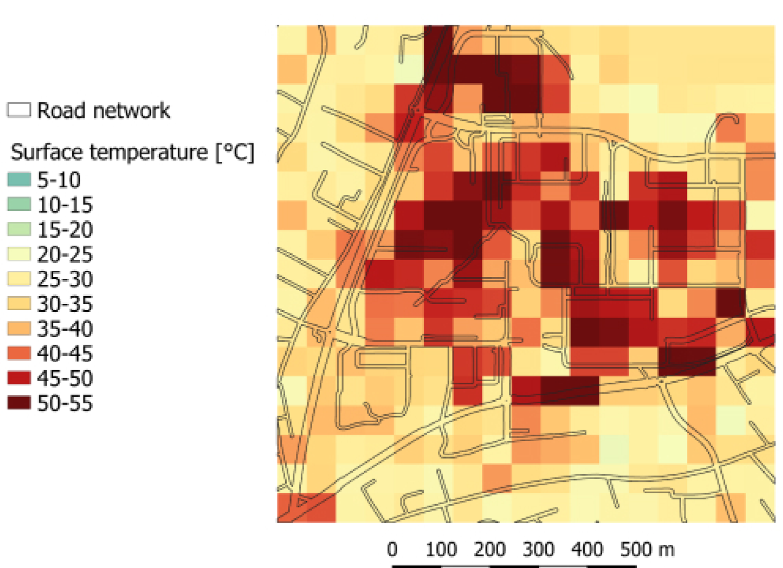
$$C\frac{\partial T_0}{\partial t}z = Q^* - Q_H - Q_E - Q_G \qquad (Wm^{-2})$$

These models require land cover and meteorological data inputs such as reference air temperature, relative humidity, incoming and outgoing radiation. (Oke et al., 2017)

MODELING PROCESS



MESO-SCALE MODEL - TARGET



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- large coverage
- several temperature outputs (PET, MRT, air temperature,...)
- adaptable time step

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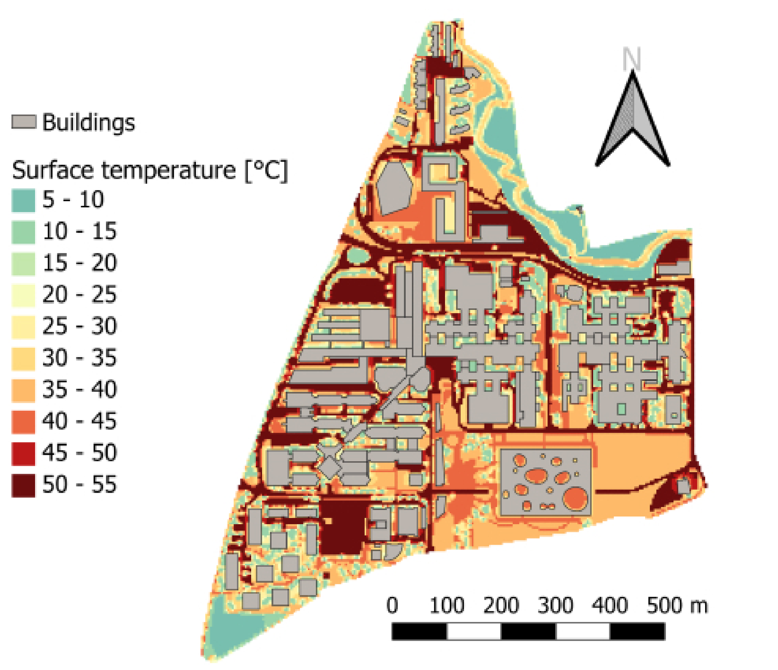
- low resolution
- fixed landcover types and properties

MICRO-SCALE MODEL - ICETOOL



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- high resolution
- user-friendly interface
- parameters control
- includes shadows

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- complexity of use
- roof temperature not included
- little documentation

URBAN HEAT ISLAND

The urban heat island phenomenon is caused by the large capacity of urban land surfaces and the built environment to absorb sun radiation and retain heat.
This results in variation in land surface and air temperatures between urban and rural areas. Consequently, the magnitude of the UHI effect is assessed by measuring the temperature difference between urban and rural areas.

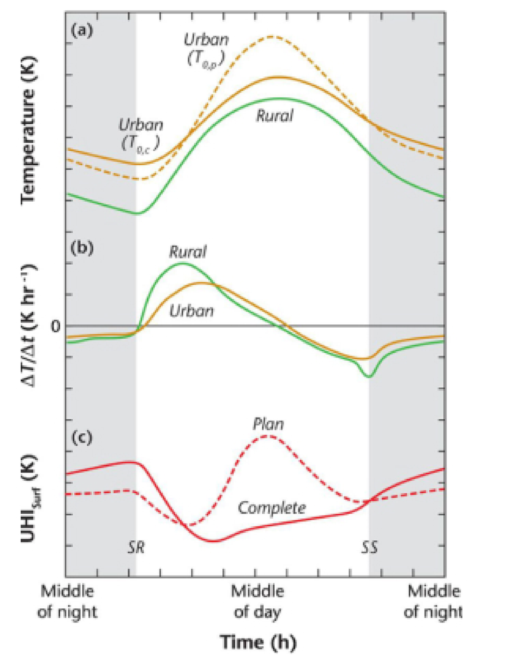


Figure 1. Surface urban heat island

Schematic (a) temporal variation of urban complete, urban plan and rural surface temperature on a day with fine weather, (b) associated urban complete and rural warming and cooling rates, and (c) temporal evolution of the UHIsurf for both the plan and complete surface. Vertical scale units are approximately 5 K, 1 K/h and 2 K respectively. (Oke et al. 2017)

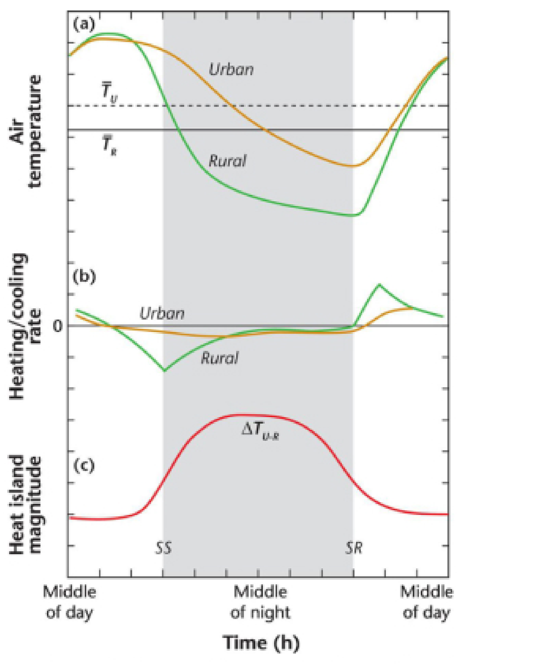
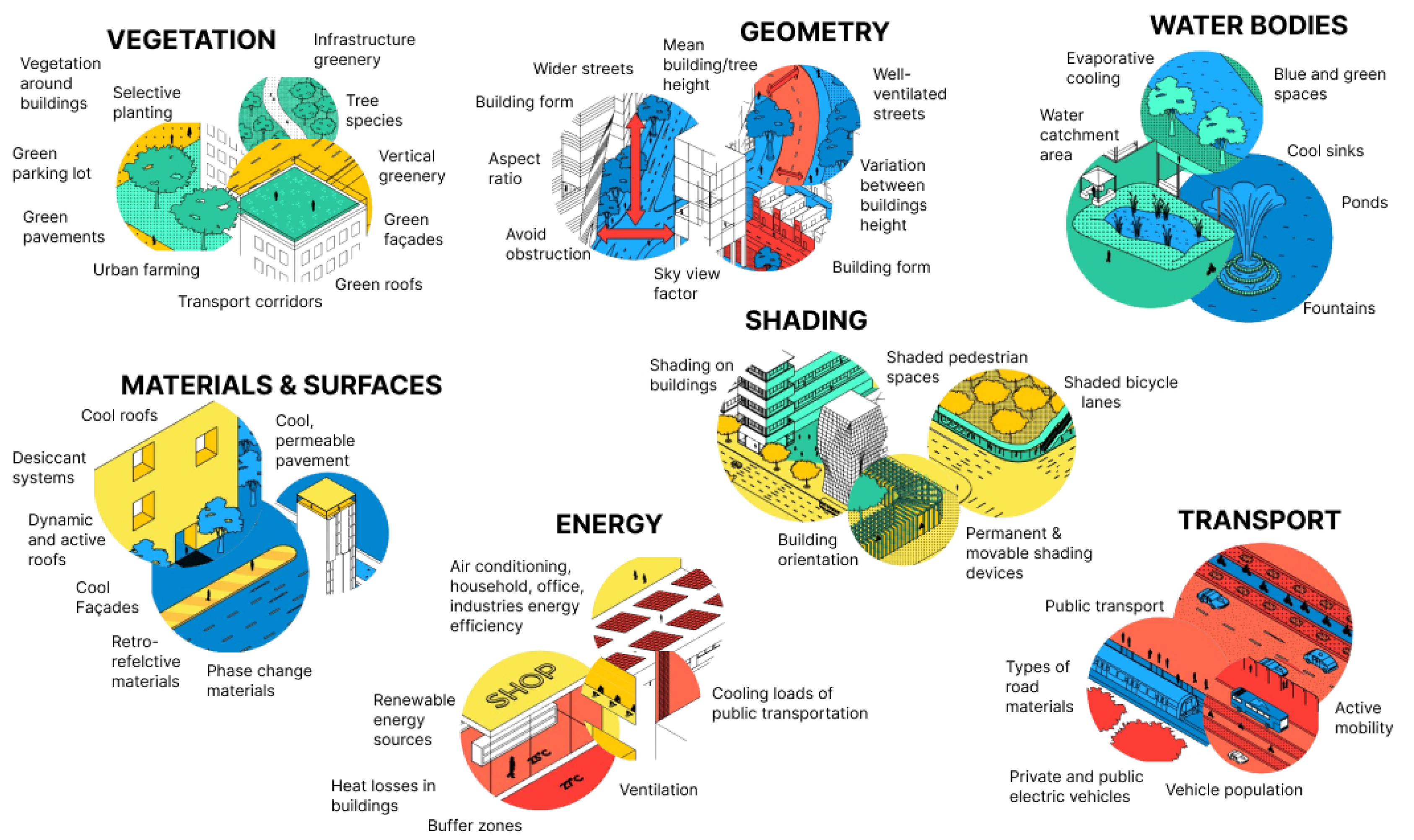


Figure 2. Canopy layer urban heat island

Schematic of (a) temporal variation of urban and rural air temperature on days with fine weather, (b) the associated warming/ cooling rates, and (c) the temporal evolution of the UHIucl. Vertical scale units are approximately 2 K for air temperature and heat island magnitude and 2 K/h for the heating and cooling rates. (Oke et al. 2017)

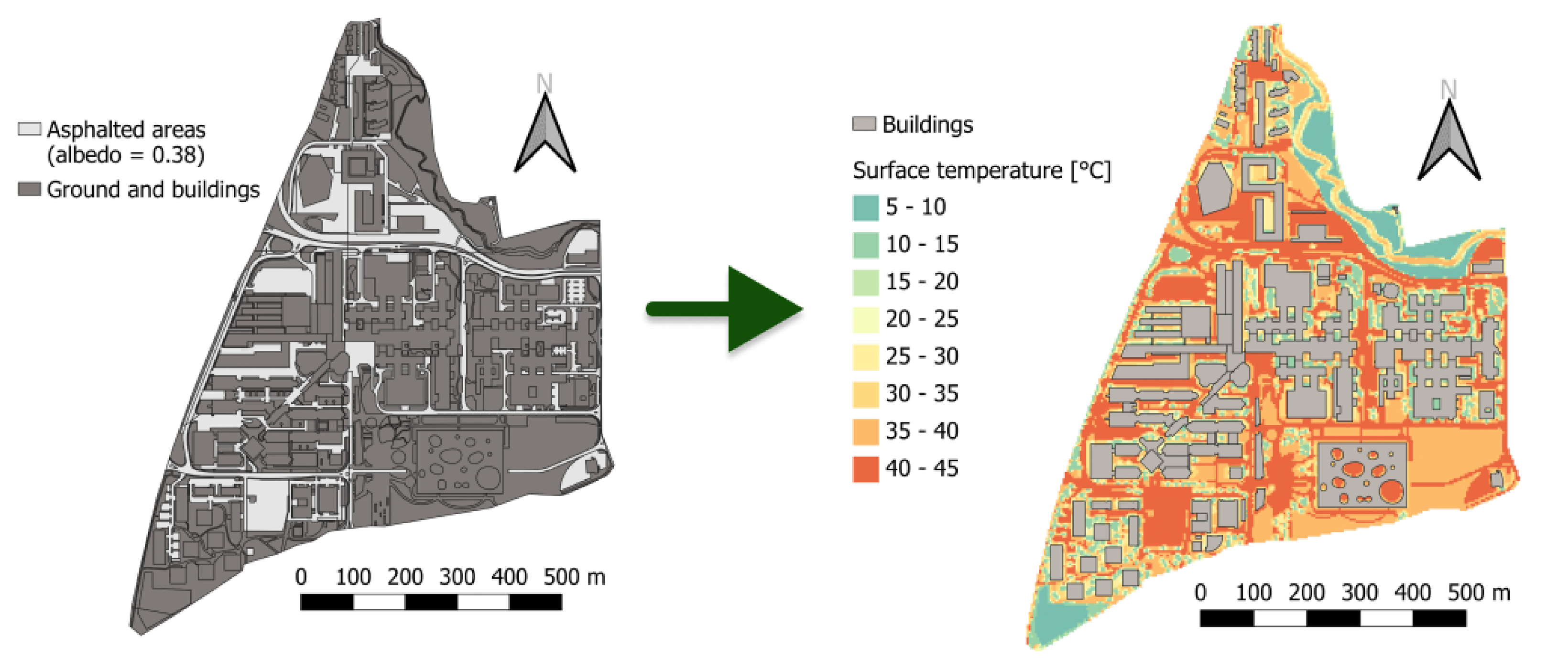
MITIGATION TECHNIQUES & IMPLEMENTATION



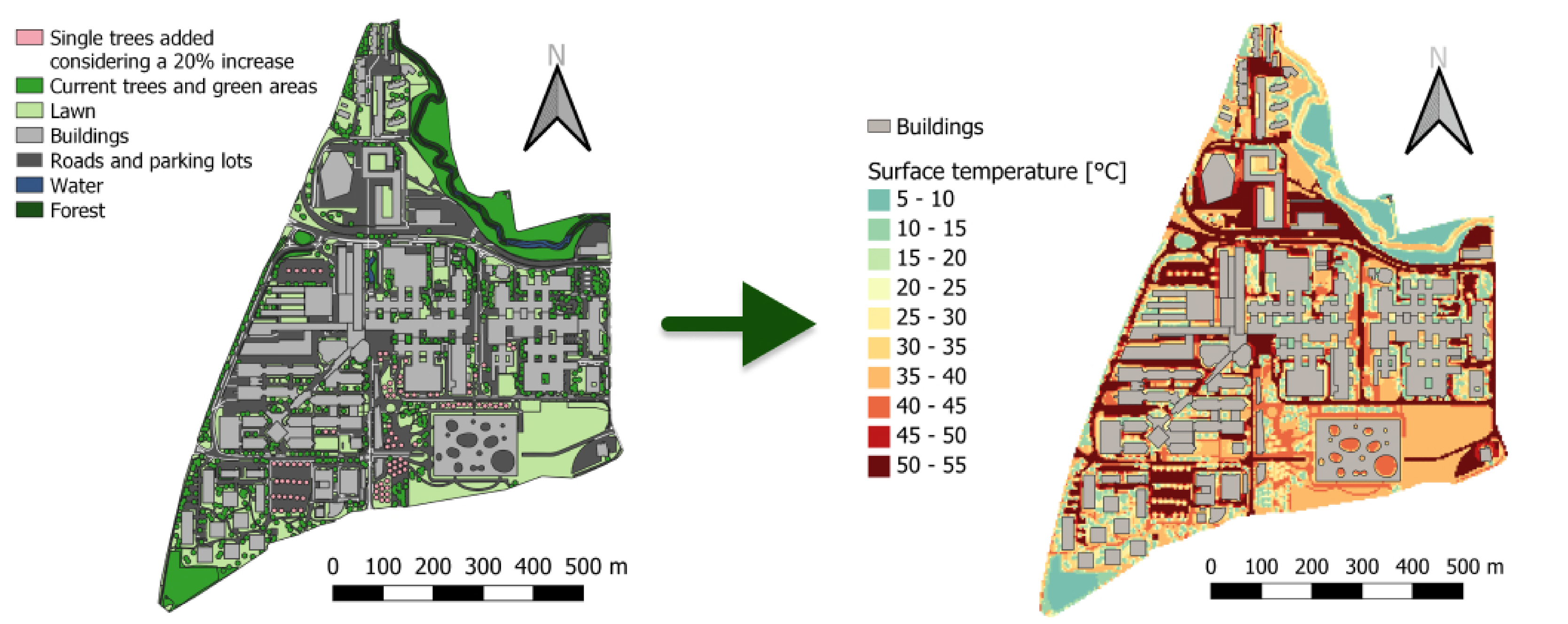
(Ruefenacht and Acero, 2017)

Several types of mitigation strategies can be implemented to reduce the impacts of urban heat islands.
Two development strategies based on surface materials and vegetation have been implemented in the base scenario and numerically evaluated with ICEtool.

MATERIALS AND SURFACES - INCREASE IN SURFACE ALBEDO



VEGETATION - TREE PLANTING



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- Ruefenacht, L., & Acero, J. A. (2017). Strategies for Cooling Singapore: A catalogue of 80+ measures to mitigate urban heat island and improve outdoor thermal comfort [Publisher: Cooling Singapore (CS)].
- Oke, T. R., Mills, G., Christen, A., & Voogt, J. A. (2017). Urban climates. Cambridge Uni-versity Press.
- Avdan, U., & Jovanovska, G. (2016). Algorithm for Automated Mapping of Land Surface Temperature Using LANDSAT 8 Satellite Data. Journal of Sensors, 2016, e1480307. https://doi.org/10.1155/2016/148030 (Avdan and Jovanovska, 2016)