1 Introduction

§ 1.1 Background

Extreme summer temperatures can be as dangerous as extreme winter temperatures. More than 30,000 excess deaths were registered across Europe between June and September 2003 (Robine et al., 2008) (Figure 1.1). Besides, there is scientific evidence proving that extreme summers, far from being isolated phenomena, will become more frequent, more intense and they will last longer (Meehl & Tebaldi, 2004; Karl & Trenberth, 2003).

After the heatwave of 2003 (Robine et al., 2008; Dousset, 2011) several studies were conducted to analyse and quantify the effects of Urban Heat Islands on the health and mortality of citizens.

- The World Health Organisation Report "Improving Public Health Responses to Extreme Weather/Heat-Waves, EuroHEAT" (Meeting Report Bonn, Germany, 22-23 March 2007) highlights the fact that hot weather can kill and cause illness.
- Within the CANICULE project more than 30,000 excess deaths were observed between June and September 2003 (Robine et al., 2008).
- A ten-year analysis of 15 European cities, carried out in the PHEWE4 project, estimated a 2% increase in mortality in northern cities, and a 3% in southern cities for every 1°C increase in apparent temperature above the city threshold level.

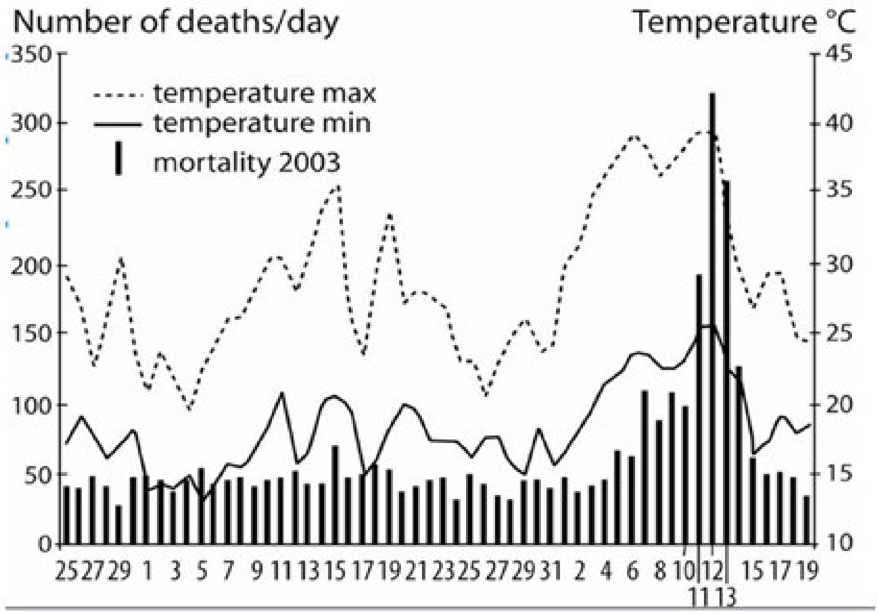

FIGURE 1.1 Graph showing the number of deaths/day related to the temperatures in Paris during the heatwave 2003 (Dousset, 2011)

Heat waves wreak havoc especially in cities, where the Urban Heat Island effect increases the daily average temperature and prevents them from cooling down during the nights. Urban Heat Islands are caused by the changes human constructions introduce in the radiative and thermal properties of the environment. The annual mean air temperature difference between the city and its rural environment ranges from 1 to 12°C (EPA, 2016).

The most appropriate tool for the systematic assessment of heat islands at city and regional scale is remote sensing, which allows for analysing surface temperature maps and for producing images revealing the distribution of other parameters influencing UHI (imperviousness, greenery, etc.).

Although there are many scientific peer-reviewed journal articles studying the Urban Heat Island effect in depth for different case study cities around the world from a climatological perspective (Dousset, 2007; Yang Lui, 2009), there seems to be a gap between the sophisticated available technologies (remote sensing), and the local UHI policies for the vast majority of medium-size to large cities. Urban planners punctually use images processed by remote sensing, but our discipline has not appropriated such a powerful tool yet.

The objective of this research is to explore the potential of the use of remote sensing technology for urban planners to be able to analyse the thermal behaviour of cities, in order to generate action plans for thermal masterplanning at the scales of the region and the city.

There are two main heat island types: the surface UHI and the atmospheric UHI, and they have different behaviours and different identification methods.

The surface heat island refers to the surface temperature difference between the rural and the urban environment, which has its greatest intensity during summer days, ranging between 10 and 15°C. The surface temperature difference during night-time ranges between 5 and 10°C. Remote sensing is the usual tool for surface temperature estimation (EPA, 2016).

The atmospheric heat island refers to the air temperature difference between the rural and the urban environment. Peak intensity occurs after sunset (due to the release of heat stored in the built environment). There are two types of atmospheric heat islands (Figure 1.2 and Figure 1.3):

- Canopy layer urban heat islands exist in the layer from the ground to below the tops of trees and roofs. It is the most common one when speaking about UHI.
- Boundary layer urban heat islands start from the rooftop and treetop level and extend up to the point where urban landscapes no longer influence the atmosphere.

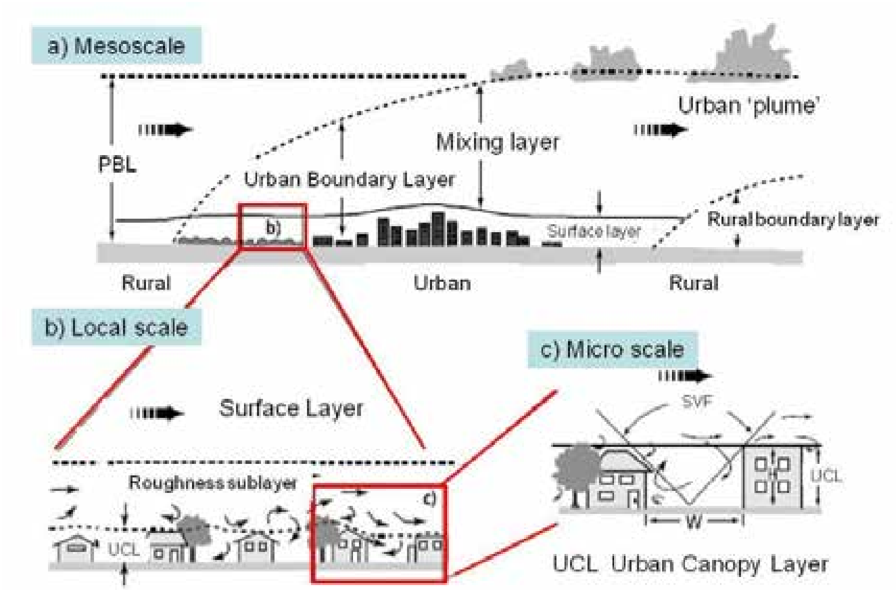

FIGURE 1.2 Schematic of climatic scales and vertical layers found in urban areas. Planetary Boundary Layer (PBL), Urban Boundary Layer (UBL) and Urban Canopy Layer (UCL). (Oke, 1987).

Feature	Surface UHI	Atmospheric UHI
Temporal Development	• Present at all times of the day and night • Most intense during the day and in the summer	• May be small or non-existent during the day • Most intense at night or predawn and in the winter
Peak Intensity (Most intense UHI conditions)	• More spatial and temporal variation: ▪ Day: 18 to 27°F (10 to 15°C) ▪ Night: 9 to 18°F (5 to 10°C)	• Less variation: ▪ Day: -1.8 to 5.4°F (-1 to 3°C) ▪ Night: 12.6 to 21.6°F (7 to 12°C)
Typical Identification Method	• Indirect measurement: ▪ Remote sensing	• Direct measurement: ▪ Fixed weather stations ▪ Mobile traverses
Typical Depiction	• Thermal image	• Isotherm map • Temperature graph

FIGURE 1.3 Basic characteristics of Surface and Atmospheric Urban Heat Islands. Extracted from Reducing Urban Heat Islands: Compendium of Strategies (EPA, 2015).

Although surface and atmospheric temperatures are different, there is a significant influence of the surface temperature on the canopy air temperature, especially by night. During daytime there are large differences between air and surface temperature behaviour, while in the evening they tend to behave similarly. At night there are large differences between the city core and the countryside temperatures (Figure 1.4 and Figure 1.5).

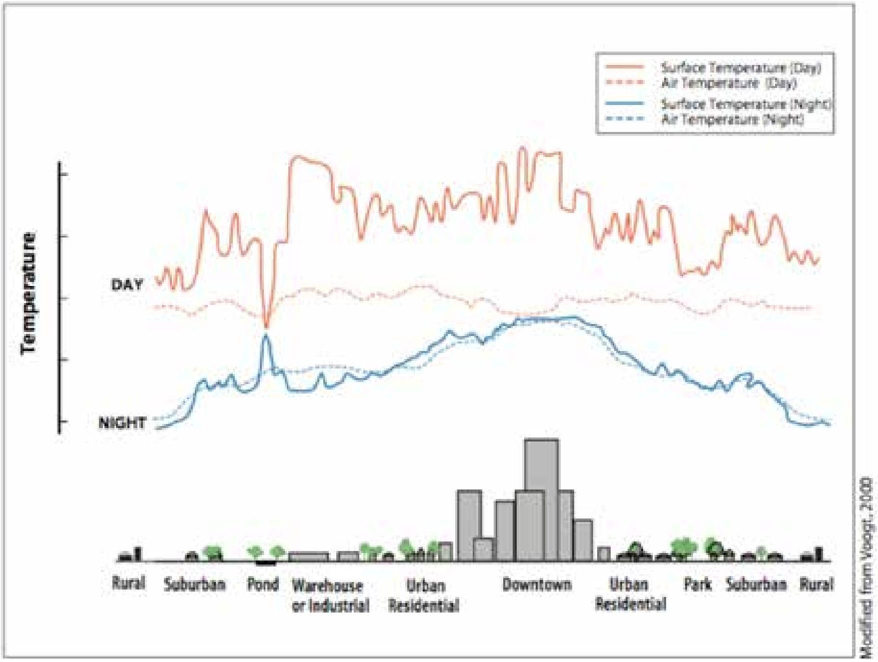

FIGURE 1.4 Variations of Surface and Atmospheric Temperatures. Extracted from Reducing Urban Heat Islands: Compendium of Strategies (EPA, 2015).

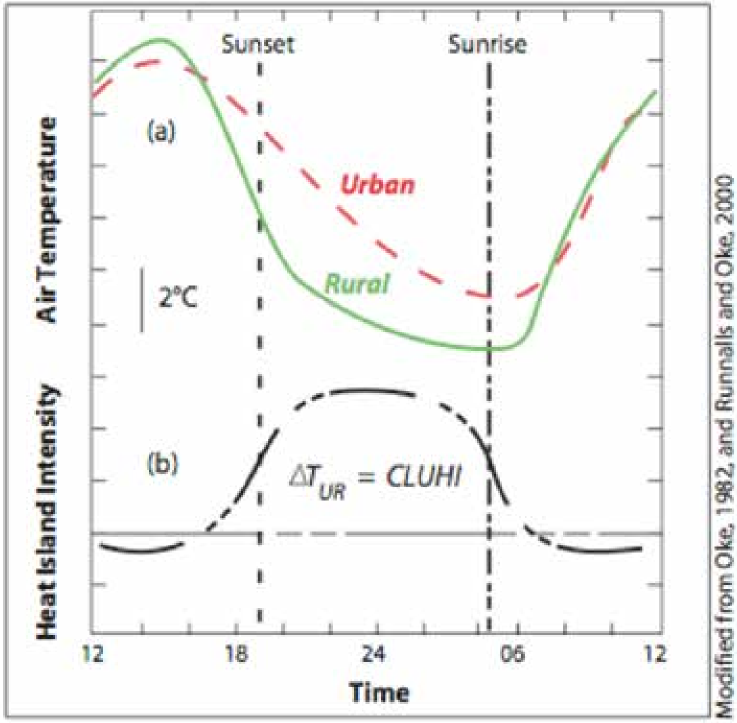

FIGURE 1.5 Conceptual drawing of the diurnal evolution of the UHI during calm and clear conditions (EPA, 2015).

§ 1.2 Overall UHI analysis and mitigation strategies

There are certain generic validated conclusions referring to UHI mitigation, however these are often not site specific, and thus should often be complemented by the use of tools to customise the assessment.

There are three types of mitigation actions to reduce UHI, at neighbourhood, city and regional scales. These will be discussed here.

§ 1.2.1 References at neighbourhood scale

- Climate zones London (Chandler, 1965).
- Meteorologically significant land uses in St Louis (Auer, 1978).
- Urban terrain zones Ellefsen (1990).
- Climatotopes in Metropolitan Hannover (Wilmers, 1991).
- Climatope classification of the region of Basel (Scherer, 1999).
- Urban climate zones (Oke, 2004).
- Local climate zones (Stewart & Oke, 2012).
- Remote sensing to define urban climate zones of Toulouse (Houet & Pigeon, 2011).
- Remote sensing for the definition of urban structure types in the city of Munich (Heiden et al., 2012).
- Object based classification to map urban structure typologies in Munich (Wurm et al., 2010).
- Remote sensing to define land-use classification produced for metropolitan Atlanta (Tang, 2007).
- The New Köppen-Geiger map created by the Council for Scientific and Industrial Research (CSIR) in South Africa (Conradie, 2016) divides the country in climatic zones (Köppen-Geiger) and suggests specific passive design strategies for each of them.

§ 1.2.2 References of urban studies

- Greenery (roof and pavement):
  - Publications that study the relationship between Normalised Difference Vegetation Index (NDVI) and other UHI-related parameters:
    - For fully vegetated surfaces NDVI is approximately 0.78, partially vegetated surfaces 0.33, dark asphalt areas 0.09, and bright concrete areas 0.07 (Richter & Muller, 2005).
    - Several studies (Kurn et al. 1994; Sailor 1995) estimate that the near-surface air temperatures over vegetated areas were 1°C lower than background air temperatures.
    - Imperviousness coefficient has a stronger linear relationship with land surface temperature (LST) values than with NDVI (Yuan and Bauer 2007), particularly in bare soil locations (Carlson et al. 1994).
    - The difference in urban and rural NDVI is linearly related with the difference in urban and rural minimum air temperatures (Gallo et al. 1993).
    - The heat fluxes can be expressed as a function of the vegetation indexes in rural environments (Choudhury et al., 1994; Carlson et al., 1995).
  - Studies that analyse the factors influencing the cooling effect of urban parks:
    - The size of the parks (Von Stulpnagel et al., 1990; Upmanis, 1998; Cheng, 2014).
    - The height and structure of the surrounding constructions (Upmanis et al., 1998; Jauregui, 1975, 1990-1991; Spronken-Smith, 1994).
    - The design of the parks. During daytime the local cool island intensity is related to the area of trees and shrubs inside the park (Cao et al., 2010; Potcher et al., 2006; Yu et al., 2006; Zhou, 2011). During night-time the coolest parks are those without trees (Chang, 2007; Taha, 1991).
    - Vegetation reduces the near-surface air temperature on average by 1 to 4.7°C, particularly during night-time when the UHI intensity is high (Kleerekoper et al., 2012; Li & Norford, 2016).
    - Assessments of the thermal load in terms of surface temperature in Tel Aviv demonstrated that the relatively low vegetation cover to free space ratio decreases the cooling effect of residential areas (Rotem-Mindali et al., 2015).
- Albedo. Albedo is the index representing the surface reflectivity. It indicates the fraction of short-wave radiation that is reflected from land surfaces into the atmosphere. When a surface albedo is 0 it doesn't reflect any radiation, and when it is 1 all the incoming radiation is reflected to the atmosphere.
  - Most US and European cities have albedos of 0.15–0.20 (Gao et al., 2014; Prado & Ferreira, 2005; Akbari et al., 2001; Taha, 1997).

    - A white surface with an albedo of 0.61 is only 5°C warmer than ambient air whereas conventional gravel with an albedo of 0.09 is 30°C warmer than air (Taha et al., 1992).
    - Increasing the surface albedo from 0.25 to 0.40 could lower the air temperature as much as 4°C (Taha et al., 1988).
    - An increase of 0.1 of the hotspot overall albedo reduces the UHI by 1°C (Sailor, 1995).
    - The finishing materials of urban ground surfaces also have a major impact on the UHI effect (Gago et al., 2013).
    - Replacing materials with new surface cover reduces the radiative heat gain in the material and improves evaporative properties of the urban surface (Roth, 2013).
    - The current research trends in the field are focused on the development of highly reflective pavements and permeable pavements that use the cooling evaporation capacity of water (Santamouris, 2013).
    - Studies in Singapore demonstrated that the city-scale deployment of cool roofs can greatly reduce the near-surface air temperature and surface skin temperature during daytime (Li & Norford, 2016).
- Imperviousness:
    - A strong correlation was also found between paved surfaces and LST (Zhou et al., 2011; Li et al., 2011).
    - Diurnal LST is correlated with the largest patch size of the urban land use type (Cheng et al., 2014).
    - The same impervious surface produces a smaller UHI effect when it is spatially distributed (Li et al., 2011).
- Urban water surfaces and surface watering:
    - These have an average cooling effect of 1–3°C to an extent of about 30–35 m. Such functions of water are already applied in Dutch cities (Kleerekoper et al., 2012).
    - Positive thermal effects of pavement-watering in Paris during the summers of 2013 and 2014. The maximum reduction of 0.79°C, 1.76°C and 1.03°C for air, mean radiant, UTCI-equivalent temperatures and UHI-mitigation of -0.22°C have been recorded during the day (Hendel et al., 2016).
- Sky view factor. The sky view factor (SVF) was defined by Oke as the ratio of the amount of the sky seen from a given point to that potentially available (Oke, 1987). Its values range from 0 for full obstruction, to 1 for completely open areas. The average SVF in central parts of European cities ranges from 0.40 to 0.75.
    - Some studies reveal a strong relationship between the SVF and the nocturnal UHI in calm, clear nights (Svensson, 2004; Unger, 2009).
    - However, other studies reveal that the nocturnal UHI is not only affected by the horizon obstructions (SVF) but also by the thermal properties of the materials, and they do not find a correlation between the UHI and the SVF (Blankenstein & Kuttler, 2004).
- Size of the cities (Oke, 1973; Park, 1986; Fujuoka,1983; Hove, 2011).

§ 1.2.3 References at regional scale

- Cooling properties of natural landscape elements:
  - Hilly forests. Climate Analysis Map for the Stuttgart region (City of Stuttgart, 1977, 2008).
  - Parks and forests outside the city. Climate maps of Arnhem in The Netherlands (Burghardt et al., 2010).
  - Bays. Tokyo Bay, the renovation plans of the Tokyo Station vicinity aim at maximising the cool wind paths connecting the cool bay breeze with the urban hotspots (JFS, 2016).
  - Water surfaces. The role of water surfaces is unclear, but appears to depend on the size and depth of the body of water. Some studies revealed water had a positive effect on local cool island intensity (Saaroni and Ziv, 2003), while others have suggested its contribution is negligible (Cao et al., 2010).
- Cool wind corridors
  - Rivers. Often act as the best wind paths to channel sea breeze into cities (Yamamoto, 2006).

§ 1.2.4 References of the use of remote sensing for UHI assessment

- References of studies using Landsat 5TM for UHI assessment:
  - UHI analysis (Bechtel, 2011; Liu & Zhang, 2011; Rajasekar & Weng 2009; Cao et al., 2008).
  - Mitigation strategies (Rosenzweig et al., 2006; Baudouin & Lefebvre, 2014).
  - Estimation of the heat mitigation effect (Odindi et al., 2015; Onishi et al., 2010).
- Systematic analysis and mapping several UHI related parameters:
  - Surface heat fluxes (Parlow, 2003).
  - Land surface temperatures (Dousset et al., 2011).
  - Albedo (Taha, 1997; Sailor, 1995).
  - Vegetation indexes (Yuan & Bauer, 2007; Gallo et al., 1993).

§ 1.3 Systematic approach to the UHI assessment

Some researchers have attempted to create online tools to produce systematic and customised UHI assessment to analyse and develop mitigation action to palliate the effect of the UHI effect.

- The Decision support system (DSS) covers 8 metropolitan areas in the Central Europe Region (Bologna/Modena, Venice/Padua, Wien, Stuttgart, Lodz/Warsaw, Ljubljana; Budapest and Prague). Assessment of the UHI at building and the urban scale (Urban Heat Island project, 2014).
- The CE Urban Heat Island Atlas is actually an interactive digital map which allows to overlap layers of parameters which play a role in the formation of the UHI phenomenon in the Central Europe region. The different layers available are: location of the project partners, air temperature, digital elevation model, land surface temperature (day and night), normalised differential vegetation index, land cover (corine), and urban atlas land use.
- The STAR tools have been developed for the North-West region of England and they include a surface temperature tool and a surface runoff tool, which allow to estimate the impact on surface temperature and surface runoff for several land use scenarios under different temperature and precipitations scenarios (STAR tools, 2016).
- The “London unified model” (Londum) is a city-wide climate model. It has been developed for the city of London and it estimates the impact of the volume on long and short wave radiation (reflection, shadow, conduction of heat into the building and calculation of the flux into the atmosphere (Hamilton et al., 2012; University College London, 2012).
- The ADMS model was also developed within the Lucid program for the city of London, and is a neighbourhood scale model which allows to estimate the temperature and humidity depending on the building volume and surface covers (it considers albedo, evapotranspiration and the thermal admittance of surfaces) (Hamilton et al., 2012; University College London, 2012).
- EPA Mitigation Impact Screening Tool (MIST) (EPA, 2016) is a software tool developed by the US Environmental Agency to provide an assessment of the impacts of several UHI mitigation strategies (mainly albedo and vegetation increase) on the reduction of the urban air temperatures, ozone and energy consumption for over 200 US cities (Sailorand Dietsch, 2007).

These are interesting attempts to provide customised UHI assessment; however, these initiatives remain isolated examples, for specific geographical areas, analysing different indicators.

§ 1.4 The UHI in the Netherlands

The KNMI (Royal Netherlands Meteorological Institute) 2014 climate scenarios (KNMI´14) for 2050-2085 translate the research results on the global climate in the IPCC report (2013) to the Netherlands. The KNMI climate scenarios cover the vertices of likely changes in the climate of the Netherlands. The four KNMI'14 scenarios differ in the extent to which the global temperature increases ('Moderate' and 'Warm') and the possible change of the air circulation pattern ("Low value" and "High Value") (Figure 1.6) (KNMI, 2015).The global temperature rise will continue increasing in any of the four scenarios (Figure 1.7) and the amount of summer days (maximum temperature equal or above 25°C) per year will also continue rising in any of the four scenarios (Figure 1.8).

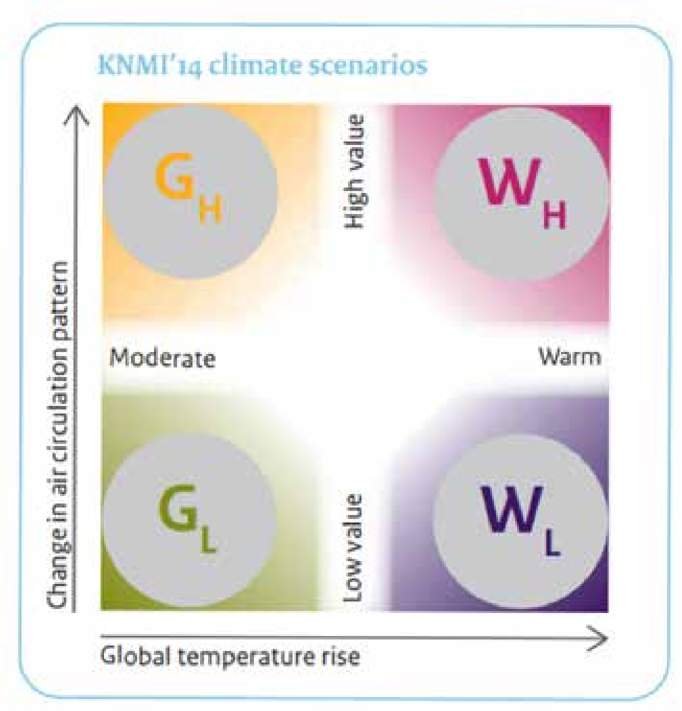

FIGURE 1.6 Schematic overview of the four KNMI'14 climate scenarios. (KNMI, 2015).

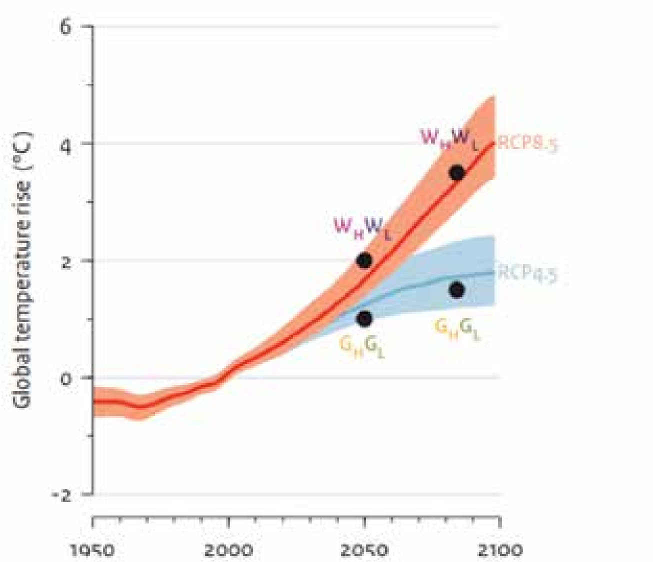

FIGURE 1.7 Global temperature rise relative to 1981-2010 based on climate model calculations performed for the IPCC 2013 report. Two different IPCC emission scenarios: RCP4.5 (stabilization) and RCP8.5 (high emissions). Coloured bands: model spread; lines: model means; dots: global temperature rise determined for the KNMI'14 climate scenarios for the Netherlands.

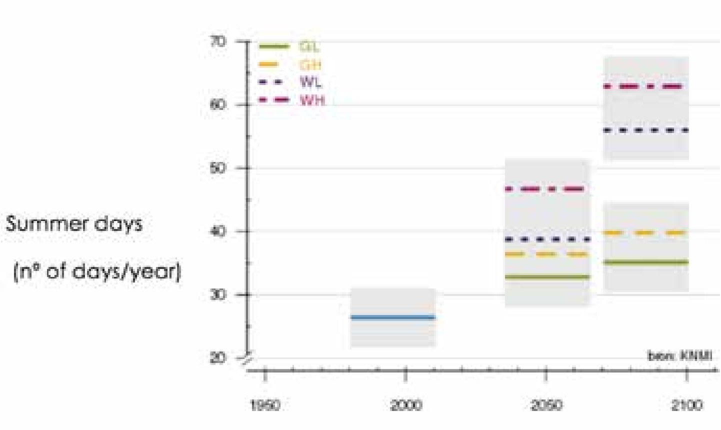

FIGURE 1.8 Average summer days per year (maximum temperature of at least 25 degrees °C) for the Bilt in the past (blue) and for the KNMI'14 scenarios, with natural variability between 30-year periods (gray).

Temperature observations and predictions in De Bilt refer to temperatures in a rural environment, which in the summer happen to be lower than in the urban (and suburban) areas.

Several studies predict an increase of the UHI in Dutch cities (Figure 1.9).

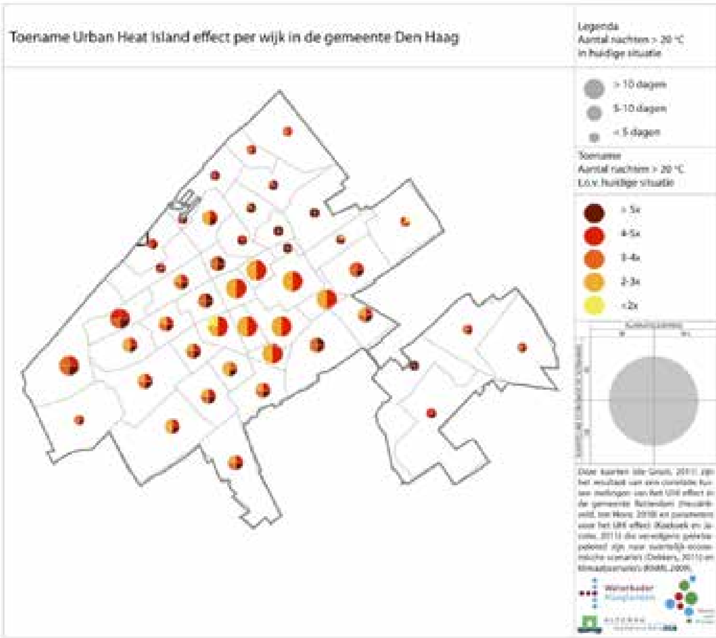

FIGURE 1.9 Increase in Urban Heat Island effect per district in the Hague. Alterra Wageningen UR (De Groot, 2011).

Thermal comfort not only depends on air temperature but also on other parameters such as atmospheric humidity, radiant temperature, wind speed, metabolic activity and clothing. Even though it does not take into consideration wind speed and radiant temperature, the approximated wet bulb globe temperature (AWBGT) is often used as a threshold value –for a specific level of activity and clothing- below which the human being experiences no heat stress.

FORMULA 1.1.

$$AWBGT=0.567Ta + 0.393e + 3.94$$

where Ta is the air temperature and e is the water vapor pressure (hPa).

Even though the Netherlands is located in a mild climate of Cfb (maritime temperate climate dominated by the polar front), a study on 24 Dutch cities (Steeneveld et al., 2011) reveals that 50% of the analysed urban areas are subject to heat stress seven days per year (Figure 1.10). The differences of absolute and relative atmospheric humidity between city and rural environment are minimal: 5% and 9-15% respectively (CPC, 2014), and thus in this case, the dry bulb temperature studies are relevant when studying the UHI.

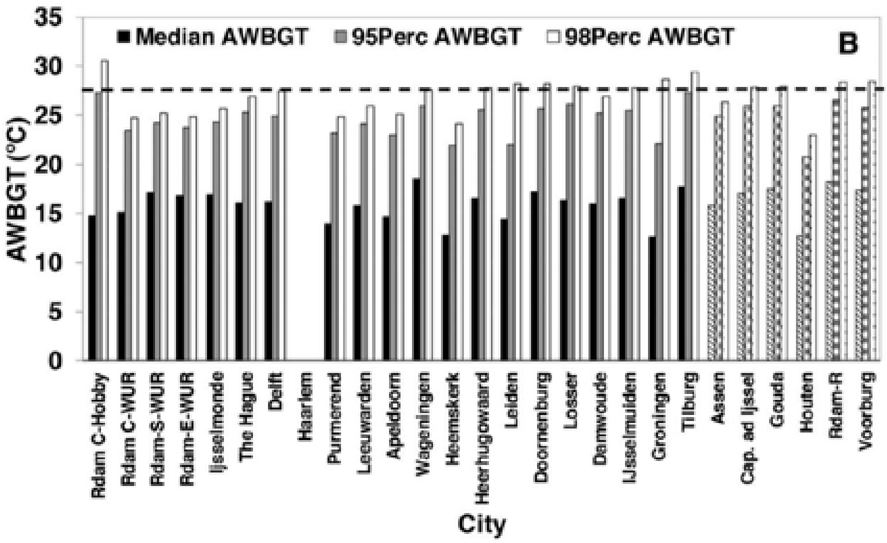

FIGURE 1.10 Observed median and percentile values of AWBGT for thes tudied cities in the Netherlands. The roof level stations are shown in modified fill (Steeneveld et al.,2011)..

In the Netherlands, the relatively recent awareness of the UHI phenomenon explains the lack of historical urban air temperature records to allow a consistent analysis of UHI patterns throughout the country (Hove et al. 2011).

Concerned by the future predictions of the KNMI scenarios, Dutch scientists, climatologists and urban planners have had to fill in the shortage of historical urban air temperature records, by using alternative methods:

- Using hobby meteorologists' data (Hove et al., 2011; Steeneveld et al., 2011; Koopmans, 2010).
- Using cargo bicycles to retrieve temperature variations through different cities during hot summer days (Heusinkveld et al., 2010; Brandsma & Wolters, 2012).
- Using satellite imagery to map land surface temperature variations during hot days (Hoeven & Wandl, 2013; Klok et al., 2010).

The revision of the literature on UHI assessment specific to the Netherlands reveals two important elements. On the one hand, existing studies are based on a wide variety of tools to fill in the lack of historical air temperature data records due to recent awareness of the phenomenon. In the authors studies (Echevarria Icaza et al., 2016a; Echevarria Icaza et al., 2016b; Echevarria Icaza et al., 2016c) the same tools were used (parameters retrieved through satellite imagery: LST day and night, NDVI, albedo, heat fluxes, etc.) to carry out the analysis at the different scales, in order to ensure the transferability and comparability of the results. On the other hand, in these studies (Echevarria Icaza et al., 2016a; Echevarria Icaza et al., 2016b; Echevarria Icaza et al., 2016c) the authors have always tried to relate the interventions proposed to the existing neighbourhood, city and regional visions (see section "societal impact"in chapter 8).

The two regions most affected by the UHI in The Netherlands are the Southern region of the country (North Brabant belongs to that region) and the Western region (South Holland belongs to that region). The Southern region concentrated in relative terms the highest amount of extra deaths during the heat wave of 2006 (reaching only during the month of July of that year more than 270 extra deaths), and the Western region (which is the densest of the country and which registered 470 extra deaths) registered in absolute terms the highest amount of extra deaths during the same period of 2006 (CBS, 2006). This is the reason why most of the case study cities and regions analysed are located in these two regions. The article "The Urban Heat Island Effect in Dutch City Centers: Identifying relevant indicators and first explorations" (Echevarria Icaza et al., 2016c) analyses six cities, five of which are located either in South Holland (The Hague, Delft, Leiden and Gouda), or in North Brabant (Den Bosch), the article "Surface thermal analysis of North Brabant cities and neighbourhoods during heat waves" (Echevarria Icaza et al., 2016b) analyses the effect in medium-size cities of the province of North Brabant, and finally the article "Using satellite imagery analysis to redesign provincial parks for a better cooling effect on cities. The case study of South Holland" (Echevarria Icaza et al., 2016a) focuses on the province of South Holland.

§ 1.5 Problem statement and objective

In a context where the spatial planner´s work requires more than ever the instruments to address the integration of multiscale and multidisciplinary parameters, it seems that the study of tools to develop urban design guidelines to positively influence the heat islands in Dutch cities and regions (where historical records of urban air temperatures are lacking) could be divided in two parts: on the one hand an overall reflection on the heat island phenomenom, the relevance of the larger scales (city to regional) for its reduction, existing technology (remote sensing) and instruments for its assessment (online platforms) and suggestion of catalising mapping strategies (game-board, rhizome, layering and drift); and on the other hand a specific assessment of the phenomenom at regional, city and neighbourhood scale for relevant locations in The Netherlands testing the instruments, tools and mapping strategies suggested in the first part.

§ 1.6 Research questions

Main research question:

Could the use of satellite imagery help analyse the urban heat in the Netherlands and contribute to suggest catalysing mitigation spatial planning guidelines implementable in the existing urban contexts of the cities, regions and provinces assessed?

The first two research subquestions are part of a generic reflection on the relevance of the large scale assessment of the UHI phenomenon.

Subquestion 1: SCALE

How would the implementation of the 1920´s regionalist premises of Geddes and Mumford affect the UHI phenomenom?

Subquestion 2: TOOLS

What satellite imagery and remote sensing processing techniques could be used for the heat island assessment at supra-urban scale?

Subquestion 3: STRATEGIES

What representation and mapping strategies could we use to ensure the proposed measures are accurate enough to actually make a difference and open enough to be compatible with the rest of elements?

Part A method is a theoretical exercise, where the authors have investigated the relevance of the large scale (city to regional) for urban heat adaptation purposes, they have selected the tools suitable for the study (satellite imagery and processing software) and they have defined the relevance of the mapping strategies for the presentation of the results. In part B results, the authors have applied the conclusions of part A method -concerning scale, tools and strategies- in order to carry out a specific assessment of urban heat in three different locations of the Netherlands, and with three different scales (Figure 1.10 and Figure 1.11).

§ 1.7 Block scheme

METHODOLOGY				
ANALYSIS				ADAPTATION
STATE OF THE ART	SCALE	PARAMETERS	TOOLS	DESIGN ADAPTATION GUIDELINES
UHI IN THE WORLD, MITIGATION STRATEGIES and EXISTING ANAL. TOOLS	Region City Neighborhoods	RURAL and URBAN ENVRNMT CHARACTERISTICS GENERATING UHI	REMOTE SENSING, GIS	WHAT TO DO TO REDUCE UHI?
		OUTPUT		
MAPPING STRATEGIES TO GENERATE URBAN PLANNING MAPS INTEGRATING MULTIDISCIPLINARY PARAMETERS (INCLUING UHI)				

FIGURE 1.11 Block Scheme

§ 1.8 Research Scheme

RESEARCH QUESTIONS	METHODS	INSTRUMENTS
Main research question		
Could the use of satellite imagery help analyse the urban heat in the Netherlands and contribute to suggest catalyzing mitigation spatial planning guidelines implementable in the existing urban contexts of the cities, regions and provinces assessed?		
PART A: METHOD. Tools and strategies to allow a mutliscale and mulidisciplinary assessment of the heat islands		
Overview of the phenomenom	Analysis and classification of UHI literature in three groups: 1/characteristics of the phenomenom in different cities, 2/Analysis of mitigation strategies 3/Analysis of online assessment tools	Books, papers, scientific journals and online assesement tools.
How would the implementation of the 1920's regionalist premises of Geddes and Mumford affect the UHI phenomenom?	Overlap and cross check of 1920's regionalist principles (original regionalist literature and recent studies and reinterpretations of this urban theory) with UHI litterature, at regional, urban and neighbourhood scales.	Books, papers and scientific journals.
What satellite imagery and remote sensing processing techniques could be used for the heat island assessment at supra-urban scale?	Literarture research to obtain an overview of satellite imagery for UHI assessment, and for mitigation proposal development.	Books, papers, scientific journals, urban planning research articles using satellite imagery for the UHI assessment (more specifically articles 4, 5 and 6 of the preset research).
What representation and mapping strategies could we use to ensure the proposed measures are accurate enough to actually make a difference and open enough to be compatible with the rest of elements?	Literarture research to obtain an overview of the role of mapping as a design tool (analysing first the nature of the urban planner's work, identifying the new parameters to be integrated in contemporary urban planner's practice, and the methods to assess the UHI at neighborhood, city and regional scale).	Books, papers, scientific journals, urban planning research articles using satellite imagery for the UHI assessment (more specifically articles 4, 5 and 6 of the preset research).
PART B: RESULTS. Neighborhood, city and regional heat island case studies in The Netherlands: remote sensing assessment and adaptation proposals		
Could the use of satellite imagery help analyse the urban heat in the Netherlands and contribute to suggest catalyzing mitigation spatial planning guidelines implementable in the existing urban contexts of the cities, regions and provinces assessed?	Interdisciplinary literature research (urban planning, climatology, geophysical, science...), part A investigation, as well as research on the urban visions for the different areas analysed in the Netherlands: Dutch city centers (The Hague, Delft, Leiden, Gouda, Utrecht and Den Bosch), North Brabant medium size cities and South Holland provincial parks (more specifically Midden-Delfland).	Landsat 5 TM and Modis 11A1 satellite imagery. Software ENVI 4.7 and GIS.

FIGURE 1.12 Research Scheme

THEORETICAL/PRACTICAL	CONTENT	PRODUCTS
THEORETICAL	OVERVIEW. Analysis of diversity of methods used for the UHI assessment. Variety of parameters -spatial contiguity, density, sprawl, storage heat flux, vegetation index, land surface temperature, albedo, sky view factor, coolspots, land use, imperviousness, social vulnerability and building vulnerability, cool wind paths,...-variety of mitigation proposals -increase of urban green, enhancement of peri-urban natural vegetation areas, consistent roof albedo modification in specific areas, maximising cooling properties of water bodies, raise social awareness, of influence the building and urban design-, and variety of online assessment tools.	CHAPTER 2 (ARTICLE 1)
THEORETICAL	SCALE. Description of regionalists principles that would help reduce the UHI.	CHAPTER 3 (ARTICLE 2)
THEORETICAL	TOOLS. Revision of parameters and mapping possibilities of satellite imagery combined with GIS for UHI assessment.	CHAPTER 4 (ARTICLE 3)
THEORETICAL	STRATEGIES. Revision of four catalyzing mapping strategies (Game-board, Rhizome, Layering and Drift) and how these could help integrate UHI considerations into the broader urban planning plans.	CHAPTER 4 (ARTICLE 3)
PRACTICAL CHAPTERS 5, 6 AND 7	CASE STUDIES. Examples of the use of satellite imagery for the analysis and mitigation proposals of the UHI in the Netherlands: in Dutch city centers (The Hague, Delft, Leiden, Gouda, Utrecht and Den Bosch), in North Brabant medium size cities and surrounding Midden-Delfland (South Holland provincial park).	CHAPTER 5 (ARTICLE 4), CHAPTER 6 (ARTICLE 5) and CHAPTER 7 (ARTICLE 6)