HOT TOWN! SUMMER IN THE CITY

A research into the relation between Rotterdam's South socially deprived neighbourhoods and the urban heat island

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Introduction

This master thesis deals with how high air temperature, as a cause of the urban heat island, is an issue of environmental justice in the city of Rotterdam. Researchers across the globe link high air temperature in urban areas to a broad range of social issues connected to poverty and socially deprivation. They argue that these socially deprived neighbourhoods, as a cause of their urban characteristics, have a strong urban heat island resulting in a high air temperature disproportionately affecting the population who on their own terms suffer from health issues and lack the means to shelter from high air temperature. Such a relation is concluded as being an issue of environmental justice whereas a part of population is disproportionately exposed to an environmental hazard.

The phenomenon of environmental justice on a city scale is relatively unknown within the European and more specific the Dutch context. With the theoretical research background one might wonder to what extends environmental injustice can be found in the city of Rotterdam. The city of Rotterdam shows a strong urban heat island with concentrated socially deprivation in specific neighbourhoods. In combination with expected temperature rise due to climate change motivates this thesis to conduct a research for the city of Rotterdam.

The thesis sets out with the use of a methodological triangulation to discover if for Rotterdam an issue of environmental justice exists. With the use of statistical analyses, observations and interviews, mapping urban characteristics and reviewing policy documents such a triangulation is conducted. From the methodology argued is that the pre-war expansion areas of Rotterdam South suffer most from high temperatures during the summer as these neighbourhoods are socially deprived where people lack the means to escape from heat.

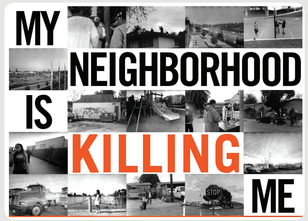
The design interventions focus on the neighbourhood Bloemhof where urban heat island adapting and mitigating design principles are applied to provide room in both the public and private space to escape from heat.

Environmental justice

Population characteristics | Environmental hazard | Urban characteristics

Environmental justice is characterized as the struggled against the inequitable distribution of environmental hazards and goods and the access to the decision-making process to have a healthy environment in which to live, learn, and work (EPA, 2016). This raises the question if low income groups or minority residents are disproportionately exposed to environmental hazards (Huang et al., 2011; Pearsall & Pierce, 2010). On a global level such effects are often disproportionately left to the poor (Millennium Ecosystem Assessment Board, 2005).

Research show that the inequitably distribution of environmental hazards can also be seen on the city scale. In a research on the heat wave in Chicago in 1995 the relation between urban heat, poverty and age proofed higher risk due to socio-economic conditions. The spatial pattern of the land surface temperature within the city showed an inequitable distribution of heat, as an environmental burden and this distribution correlated positively with socially deprived neighbourhoods. The residents of the neighbourhoods are characterized by low income, low education and ethical minority are more exposed to higher land surface temperature (Huang et al., 2011).

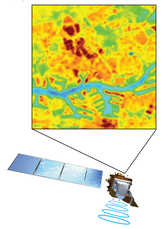


Urban heat island

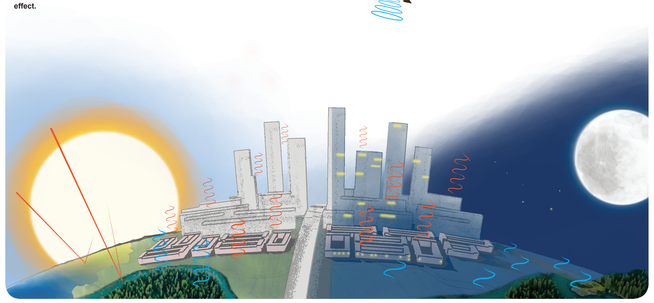
Many cities have the tendency to warm up during the day and remain warm during the night. This is also known as the urban heat island and is the relative higher air and surface temperature in the city compared to its rural surrounding areas (Gartland, 2008).

Due to solar radiation and anthropogenic heat the city conserves heat and re-emits this over time. In regard to this physical theory the main causes of urban heat island are urban surfaces who reduce evapotranspiration, increase heat storage, increased net radiation, reduced convection and increased anthropogenic heat. As mentioned before asphalt for example is a material that is dark and impermeable and stores a lot of energy and moisture is unable to evaporate this heat (Gartland, 2008). This energy in the asphalt is then overtime radiated. One might have noticed this by putting his hand on asphalt after sunset during a warm summer day and discover that it is still quite warm. This radiation, build up during the ray, and re emitted at night is responsible for the urban heat island effect.

Using LandSat 8 to map land surface temperature



Characteristics contributing to the urban heat island	Effect on the energy balance
Lack of vegetation	Reduces evapotranspiration
Widespread use of impermeable surfaces	Reduces evaporation
Increased thermal diffusivity of urban materials	Increases heat storage
Low Solar reflectance of urban materials	Increases net radiation
Urban geometries the trap heat	Reduces convection
Urban geometries that slow wind speeds	Increases net radiation
Increased levels of air pollution	Increase anthropogenic heat
Increased energy use	



Overview of the design proposals

Courtyard building typology

The introduction of a courtyard building typology improves the diversity in the neighbourhood with apartments of different sizes, population density to meet growth ambition and pressure on different services and provides for coolness in the inner courtyard and private apartment. An increase of building mass, in regard of the urban heat island, seems counter intuitive. With the use of urban heat island mitigating and adapting design principles in the building design the negative effects of increase building mass are mitigated.

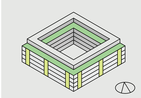
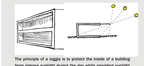
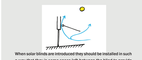


figure 1.Principle of courtyard building block.



The principle of a loggia is to protect the inside of a building from intense sunlight during the day while providing sunlight during the evening and morning and the winter (Huijbers & Dobbeleere, 2012, p. 84; Lenzholzer, 2013, p. 118)



When solar blinds are introduced they should be installed in such a way that they is some space left between the blind to provide for ventilation and the façade to prevent the air underneath the blind to warm the façade (Huijbers & Dobbeleeren, 2012).

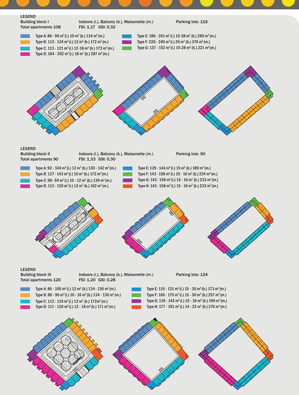
A green facade provides shading for the wall behind the green reducing the temperature of the outer wall and the inner temperature. Providing the plants with water can be troublesome and needs consideration (Lenzholzer, 2013, p. 123).

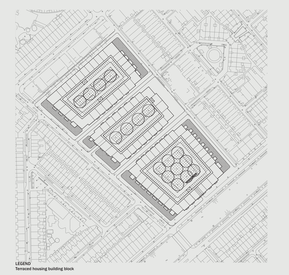
A pergola offers shade and cooling by evapotranspiration. Requires regular maintenance which can be an opportunity for communal effort and responsibility (Lenzholzer, 2013, p. 121).

With a clear distinction between the private and public realm residents recognize their own territory creating involvement in their neighbourhood. Eyes on the street provide for social control creating a feeling of safety for both residents as visitors. (Polman, 2009; Tekne & TU Delft Faculteit Bouwkunde SMART Architecten, 2016, p. 87)

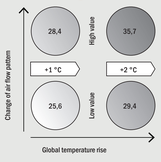
Roofs with intensive grass provide for cooling, reduce inner door temperature, reduce air pollution, storm water reduction, and provide green to its direct surroundings. It must be noted that green roofs need a strong construction, a minimum thickness of at least 25 cm, during drought irrigation and intensive maintenance (Gartland, 2008; Lenzholzer, 2013, p. 162).

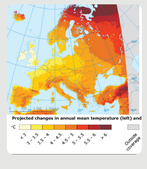
With the introduction of a heat and cold storage system the energy in the form of heat is collected and stored in an acquifer in the subsoil layers. The stored heat is available during the winter for heating. The system also works the other way around. During the summer the cooler water in the subsoil acquifer provides for cooling. Such a system would reduce energy costs and mitigated to high air temperature (Climate Proof Cities consortium, 2014).





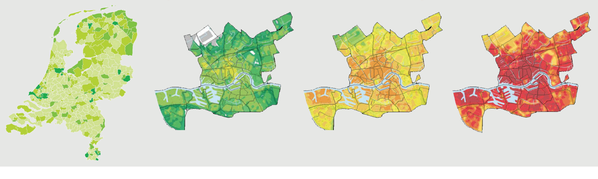
Climate change





Dutch context of Rotterdam

Expected increase of number of summer days



Statistical analyses

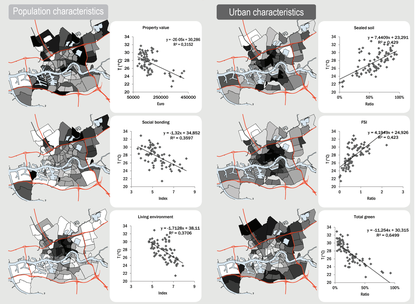
With the use of Microsoft Excel a Pearson's product-moment correlation coefficient or short Pearson correlation is computed and analysed. The Pearson correlation is a measure of the linear correlation or strength and direction of association that exist between two variables (Laerd statistics, 2016).

The Pearson correlation analysis was computed to assess the relationship between the average day summer temperature and the environmental hazard indicator of excess air quality, 8 indicators of urban characteristics and 6 indicators of population characteristics. The distribution of each indicator among the different neighbourhood is displayed with for each a graph the formula and R^2 value that indicates how well the data is correlated.

The indicators with significance R2 are:

- **Social index: social bonding**
- **Social index: living environment,**
- **Dwellings per hectare**
- **Property value**
- **Floor space index**
- **The share sealed soil ratio**
- **Total green**

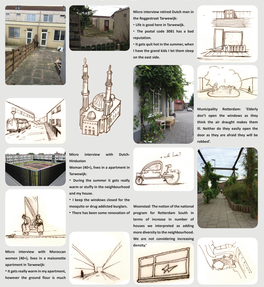
Such results fit the theory that urban characteristics of density, green and the use of impervious surfaces correlate with the land surface temperature (EEA, 2012b; Gartland, 2008; Harlan et al., 2006; Tomlinson et al., 2011; F. van der Hoeven & Wandl, 2013). The correlating indicators from the category of population characteristics are social bonding, living environment and property value. This suggests that neighbourhoods that score low on these indicators, indicating some sort of deprivation, correlate with high land surface temperatures.



Observations and urban characteristics

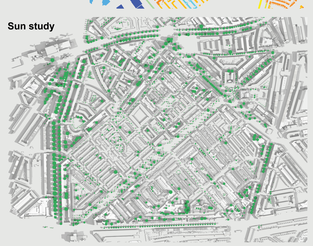
Aside from the statistical analyses the neighbourhood is assessed upon urban characteristics of green structure, density, sun and shade and building year. Observations and interviews are done to verify the findings from both the statical analyses and assessment of the urban characteristics.

Green structure



Floor space index

Sun study



Greening the private and public space

Greening the private and public space revolves around three proposals of greening the private gardens, greening streets and facades and public squares.

Greening the private gardens is both an effort by the residents and the housing corporation. Such an effort provides for the resident a relative easy to maintain garden that gets less warm during hot summer days and are more enjoyable. With removing titles the water storage capacity of the soil increases as water is more able to infiltrate in the surface.

Greening streets is process in which the municipality, housing corporation and residents engage in a neighbourhood deal. Such deals revolving around greening provides neighbourhood residents the freedom to maintain vegetation in their street to their own liking. The municipality provides tips, material and money.

Greening public squares range from easy catches like adding a bench in the right spot to square overarching roof. Some squares have already been redesigned but may still score low on the quality of shade providing trees. As these are often already planted and need time to grow and such intervention are left out. Other squares are improved with more vegetation and communal gardenings.

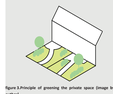


Figure 3.Principle of greening the private space (Image by author).

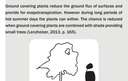
figure 4.Principle of greening a street (Image by author).

A green facade provides shading for the wall behind the green reducing the temperature of the outer wall and the inner temperature (Lenzholzer, 2013, p. 123).

When there is a lack of space greening street lanterns can provide for an alternative for trees. The effect is less then a full grown tree but should not be neglected. (Lenzholzer, 2013, p. 172).

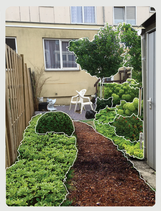
Ground covering plants reduce the ground flux of surfaces and provide for evapotranspiration. However during long periods of hot summer days the plants can wither. The chance is reduced when ground covering plants are combined with shade providing small trees (Lenzholzer, 2013, p. 160).

Replacing the paved surfaces of parking spaces in the public space with semi paved tiles provides for more water storage as water is more able to infiltrate in the soil and reduces the ground heat flux (Lenzholzer, 2013, p. 179; IO Consultants,



Conscious community takes care of maintenance in the neighbourhood with support of the municipality. The neighbourhood provides for communal services that are managed by the community (Tekne & TU Delft Faculteit Bouwkunde SMART Architecten, 2016).

Small trees provide for shade and evapotranspiration. Since the roots of the tree grow deeper the chance of withered is much lower (Lenzholzer, 2013, p. 130)..



Terraced building typology

The introduction of a terraced building block typology and a 'singel' alongside Putsebocht a new water body with rich vegetation. Such a water body has the potential to mitigate the urban heat island as it provides for water for evapotranspiration and is beneficial for the water capacity of the neighbourhood.

By combining the parking plots within the building block more room becomes available for vegetation and water. The terraced building block are divided in four separate blocks, improving the network by interconnecting public spaces.

figure 2.Principle of terraced building block.

The introduction of large trees provides for evapotranspiration and shade which enables a reduction of 50% of radiation within the drop shadow of the tree (Lenzholzer, 2013). In the street 'Putsebocht' there are already some big trees and these should be integrated in the design.

Parking solution in where the parking garage acts as a public space accessible from the dwellings.

A minimum of bigger trees assists provide for shade, evapotranspiration and aesthetical value. Within the urban design there are two considerations. Firstly smaller plants can dry and therefore should be placed within the drop shadow of the large trees. Secondly larger plants my obstruct inner-visibility and hose a deteriorating effect on social control (Lenzholzer, 2013, pp. 134, 165).

The introduced water body provides for water capacity and vegetation. The lated singel is used as it not only is part of the water management system it also provides for public space with parkeld greenery and pedestrian routes. As such a singel is a urban design element that can provide for greenery and surface water capacity (Meyer, 2012).

The effectivity of the water body increases with vegetation as these provide shade, evapotranspiration of heat is beneficial for bio diversity (Lenzholzer, 2013, p. 169).