The transformation of the

Transformatorplein

(UN)PAVING THE WAY TO A GREENER SQUARE

Team 2557 - Creating a green oasis in Arnhem

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October 2020

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Executive Summary

The citizen's initiative "Groen Transformatorplein Arnhem" (GTA) reached out to Wageningen University to commission a project aiming to turn the Transformatorplein into an urban green space. Currently, the Transformatorplein is a bare square with a lot of concrete and little vegetation. The initiative would like to see the square transformed into a green oasis that provides relief from urban environmental factors like heat and noise pollution amongst others, and increases the provision of ecosystem services. The project team is going to explore various greening scenarios and their associated complexity that could facilitate this goal. Ideas and suggestions from the initiative will be accommodated in the process. It is highly recommended to increase greenspaces on the square. One of the most effective measures to do so would be larger vegetation like trees. Further recommendations can be found in the report. The commissioners will receive an informative leaflet about the main key points of the project as well as a 12-page leaflet with an overview of the greening scenarios to present to the municipality and investors. The team will attend the task with perseverance to find the most feasible solutions for the Transformatorplein, applying their knowledge in urban environmental systems. Each team member will be dedicating 205 hours to the project. The final product will be delivered to the commissioners by the 16th of October 2020.

Samenvatting

Het burgerinitiatief "Groen Transformatorplein Arnhem" (GTA) benaderde de Wageningen Universiteit met een project om van het Transformatorplein een stedelijke groene ruimte te maken. Op dit moment is het Transformatorplein een kaal plein met veel bestrating en weinig vegetatie. Het initiatief wil dat het plein wordt getransformeerd tot een groene oase die verlichting biedt voor onder andere stedelijke omgevingsfactoren als warmte en geluidsoverlast en die de voorziening van ecosysteemdiensten vergroot. Het projectteam onderzoekt verschillende vergroeningsmaatregelen, de impact op ecosysteemdiensten en de bijbehorende complexiteit om dit doel te faciliteren. Ideeën en suggesties van het initiatief en andere belanghebbenden worden in het proces meegenomen. Het is sterk aanbevolen om het aantal groene ruimtes op het plein te verhogen. Eén van de meest effectieve maatregelen om dit te bewerkstelligen is het aanleggen van bomen. Verdere aanbevelingen kunnen in het rapport gevonden worden. De opdrachtgevers ontvangen een informatieve brochure over de belangrijkste kernpunten van het project en een folder met een overzicht van de vergroening opties om aan de gemeente en de investeerders te presenteren. Het team zal aan het project werken om de meest haalbare oplossingen voor het Transformatorplein te vinden door hun kennis in stedelijk management toe te passen. Elk teamlid besteedt 205 uur aan het project. Het eindproduct wordt op 16 oktober 2020 aan de opdrachtgevers geleverd.

GLOSSARY

This project concerns the possible improvement and transformation of urban spaces at the Transformatorplein and includes technical aspects related to this subject. Therefore, this section provides a description of the terminology that is used throughout the proposal and the final product. A list of the most common terminologies and related descriptions can be found here.

URBAN GREEN SPACES: Open spaces in urban areas – such as parks, residential gardens, trees, shrubs, and grass – which are directly (recreation) or indirectly (positively influencing the urban environment) available for the citizens (Haq, 2011; Kabisch & Haase, 2013).

GREENING MEASURES: Interventions that aim to make cities more sustainable by increasing the quantity and quality of urban greenery (urban green elements). Examples are the planting of trees, the building of green walls, green roofs, and the renovation or transformation of industrial areas or paved public places into urban green spaces (Bowd et al., 2015).

ECOSYSTEM: "A dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit. Humans are an integral part of ecosystems" (MEA, 2003, p.3).

ECOSYSTEM SERVICES: Benefits that people obtain from ecosystems (MEA, 2003). Urban green spaces can provide numerous ecosystem services to citizens. Some examples of ecosystem services are water regulation, temperature regulation, noise reduction, air pollution control, provision of recreation, and enhancement of well-being (MEA, 2003).

WOORDENLIJST

Dit project gaat over de mogelijke verbetering en transformatie van stedelijke ruimtes op het Transformatorplein en bevat technische aspecten die gerelateerd zijn aan dit onderwerp. Deze sectie geeft een beschrijving van de terminologie die uitgebreid gebruikt zal worden in het voorstel en het eindproduct. Een lijst van veelvoorkomende terminologie en gerelateerde beschrijvingen is hier te lezen.

STEDELIJKE GROENE RUIMTEN (URBAN GREEN SPACES): Publieke ruimtes in stedelijke gebieden – zoals parken, tuinen, bomen, struiken, en gras – die direct (recreatie) of indirect (hebben een positieve invloed op het stedelijke gebied) beschikbaar zijn voor de burgers (Haq, 2011; Kabisch & Haase, 2013).

VERGROENINGSMAATREGELEN (GREEN MEASURES): Interventies met het doel om stenen duurzamer te maken door de kwantiteit en kwaliteit van stedelijk groen (stedelijke groene elementen) te verhogen. Voorbeelden zijn het planten van bomen, het bouwen van groene muren, groene daken, en het renoveren of transformeren van industriegebieden of bestrate plekken naar stedelijke groene ruimten (Bowd et al., 2015).

ECOSYSTEEM (ECOSYSTEM): “Een dynamisch complex van planten-, dieren- en micro-organisme gemeenschappen en de niet-levende omgeving waarmee deze interactie hebben as een functionele eenheid. Mensen zijn een integraal deel van ecosystemen” (MEA, 2003, p.3).

ECOSYSTEEMDIENSTEN (ECOSYSTEM SERVICES): Voordelen die mensen verkrijgen van ecosystemen (MEA, 2003). Stedelijke groene ruimten kunnen vele ecosysteemdiensten verschaffen. Enkele voorbeelden van ecosysteemdiensten zijn waterregulatie, temperatuurregulatie, lawaai vermindering, luchtvervuiling beheersing, verschaffen van recreatie, en verbetering van welzijn (MEA, 2003)

1 INTRODUCTION

The following report is meant to provide insights into different greening measures that can potentially be implemented on the Transformatorplein in Arnhem. Over the last few years, many residents of the Transformatorplein in Arnhem have increasingly experienced climate-change related issues. To be able to address their wishes for improvement of the square, the residents have joined forces as a resident initiative called "Groen Transformatorplein Arnhem" (GTA). The GTA feels that the Transformatorplein (Figure 1) has a great potential to increase the quality of life and attractiveness of the neighbourhood, and particularly of the square itself. In the initiative's perception, the square is becoming warmer and drier in the summers and offers little capacity for biodiversity. Additionally, the square is perceived as a plain, cold and uninviting area that does not live up to its full potential. Lastly, the residents believe that a climate-proof design of the square could also alleviate issues on the square such as noise pollution, strong winds, a lack of privacy, and aesthetics. They envisage that the implementation of additional green spaces or the adaptation of the current green areas has the potential to address these problems.

Figure 1 - The atmosphere and plain grounds on the Transformatorplein. Perspectives are from the monumental building on the east side of the square (left), and from the northwestern corner (right).

To start with the improvement of the square, the GTA has taken action and divided the square into three different zones for action (Figure 2). The resident initiative has contacted the municipality to remove the pavement of the first metre surrounding the houses (Zone 1) and requested for it to be replaced with plants. This reconstruction took place on the 26th of September 2020 and residents have since restored the paved surface with plants and flowers.

The GTA is now looking for potential additional greening measures that can be implemented on larger areas of the square. They would like to receive a scientific assessment of possible greening measures for the square to present to the municipality and promote throughout the neighbourhood (S. van Vliet, personal communication, September 4, 2020). Based on this wish, they contacted the Wageningen Science Shop to commission a group of consultants (AGORA) to help them in their endeavour of transforming the square. During the first intake meeting, two focus areas were mentioned: the raised vegetated zone in front of the houses (Zone 2) and the approximately 500 square metres of space between the car park and this zone (Zone 3). The car park was mentioned as an important function of the square due to the need for parking spaces for the surrounding offices and residential dwellings.

AGORA conducted the research that can be used by the GTA to both green the square as well as increase ecosystem services present. This report encompasses a full report of the research as well as the outcomes resulting in recommendations for the GTA. It functions as the foundation of the end product delivered to the GTA, consisting of a poster and leaflet.

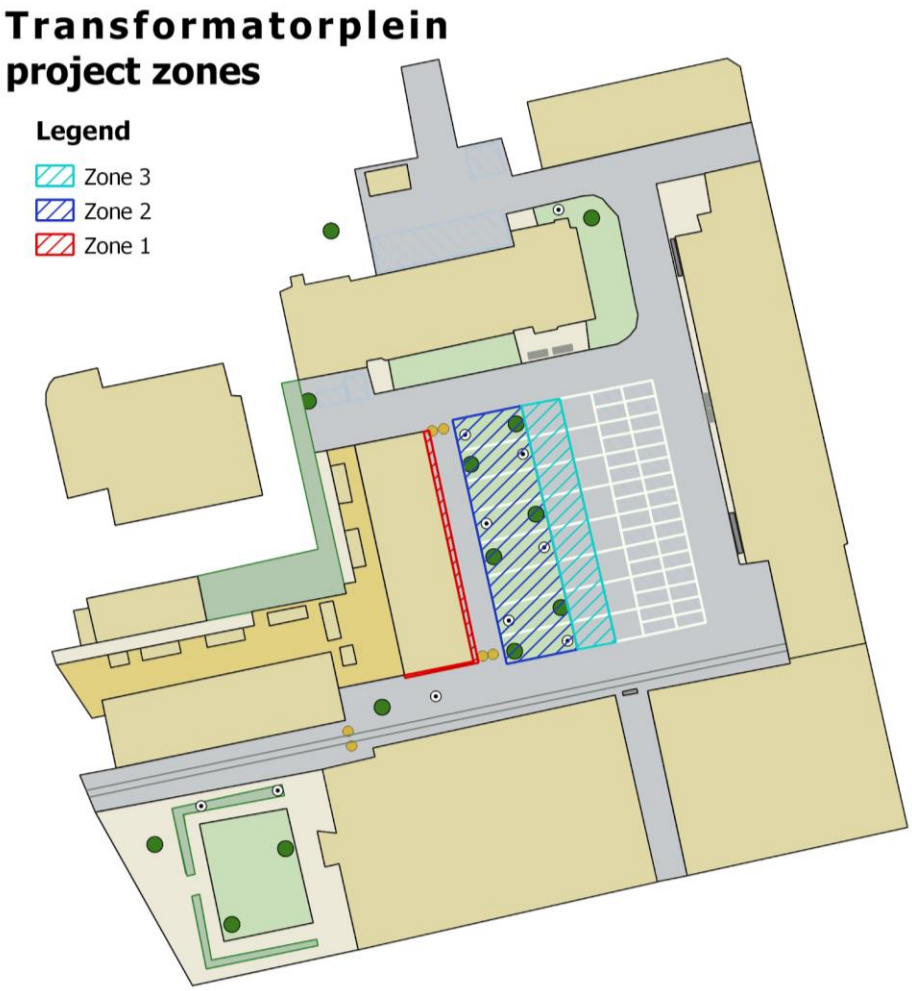


Figure 2 - The Transformatorplein with the three project zones indicated.

2 Problem Description

With its location near the Rhine River that flows through Arnhem, the Transformatorplein is close to the city centre (Figure 3). The square is surrounded by the Broekstraat, Ampèrestraat, Van Oldenbaarneveldtstraat and the Thomas J. Witteroosstraat.

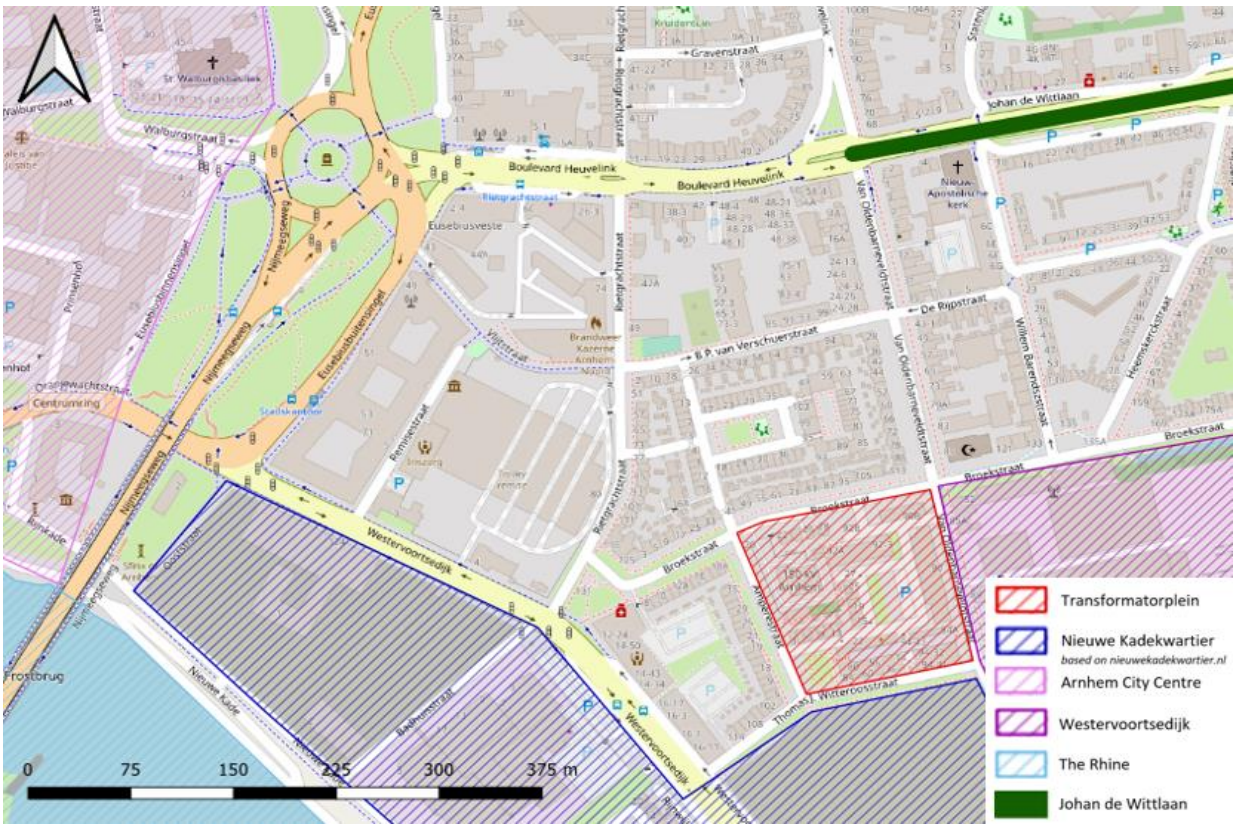


Figure 3 - The Transformatorplein is located between the Rhine, the city centre and an industrial area.

The area is a former floodplain that was transformed into an industrial area in the 20th century (Gemeente Arnhem, 2014). The Transformatorplein itself is based on the site of a former gas factory (Figure 4) which occupied the square from 1860 until approximately 1960 (Provincie Gelderland, 1996) and left behind some of the Netherlands' most polluted soil and groundwater (De Gelderlander, 2011). The pollution of the soil affects the possibilities on the square, as soil remediation may be necessary to generate a climate-proof area.

Figure 4 - The gas factory on the Westervoortsedijk in Arnhem around 1870 (Gelders Archief, n.d.).

A large reconstruction of the site and remediation of some of the soil of the old gas factory took place between 2012 and 2015 to make the area hospitable and livable (Figures 5 & 6) (De Gelderlander, 2011). The newly developed area was called the “Nieuwe Kadekwartier” and includes the Transformatorplein. In the middle of the square, the ‘Groene Bak’ was constructed; this refers to the elevated area on which grass and walnut trees grow (Figure 7).

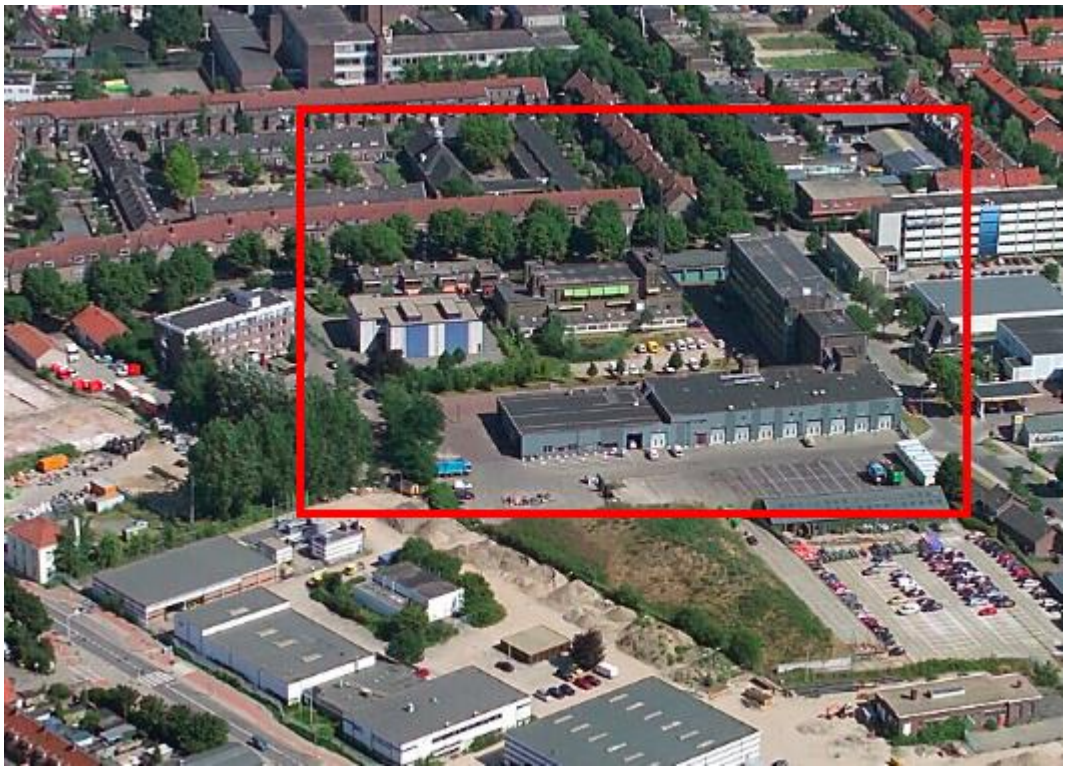


Figure 5 - The Transformatorplein from above before reconstruction started. There are many industrial buildings present in the area (Gelders Archief, 2003).

Figure 6 - The building in which the café is currently situated, frontal picture on the left (Turk, 2015a). In the right picture the small passageway between the new building and a monumental building is shown (Turk, 2015b). Pictures were taken just after the reconstruction in 2015.

Figure 7 - The outlook of the square just after the reconstruction in 2015. The elevated area is the 'Groene Bak', in which currently grass and walnut trees are growing (Turk, 2015c).

The square nowadays consists of a mix of older, monumental buildings used as offices and creative spaces, as well as modern housing units, and a large open-air car park with 32 spaces. A lot of the surfaces on the square are paved, with some grass strips along with the monumental buildings and a larger green strip, the 'Groene Bak', with grass, lamps and six walnut trees in the centre of the square (Figures 8 and 9).

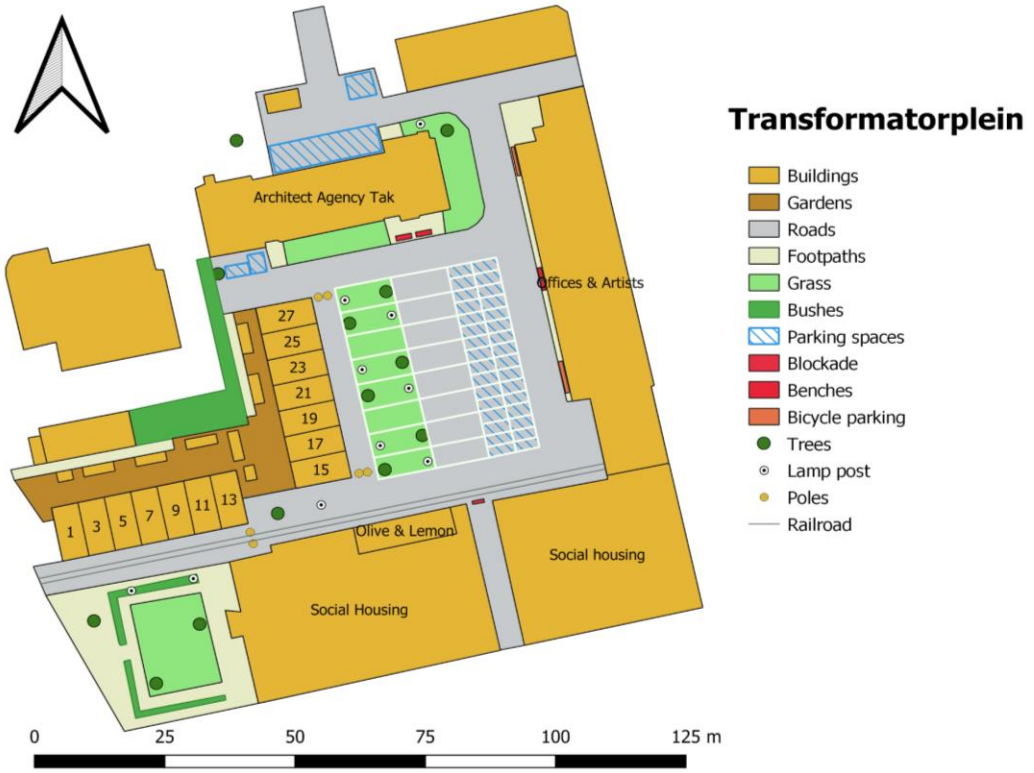


Figure 8 - Layout of the Transformatorplein's buildings and surfaces. Many of the surface materials are paved; the car park is dominant at the centre of the square. Only a small part of the square is green.

Figure 9 - The Transformatorplein from above. On the eastern and northern side, the monumental buildings are located. The buildings on the south and the east side area residential. The green spaces are dried out aside from the trees. Most of the square is paved and has a dark colour (print screen from Google Maps, recorded on the 15th of October 2020).

As visible in Figures 7, 8 and 9, only a small percentage of the square is green. Moreover, most of the surface area is paved, there are a lot of buildings and most colours are dark. These environmental factors all affect the climate as well as the experience that people have on the square. Urban environments such as the Transformatorplein have a very distinct climate compared to the less densely-built surroundings. Environmental factors, for example, pollution, high rise buildings, a high density of paved surfaces and the configuration of streets, all have a significant effect on the water flow, air temperature and wind in cities. The climatic difference between urban areas and closely located countrysides is caused by the urban heat island effect. This effect leads to changes in both the large-scale and small-scale climate. The wind is lower in speed but very chaotic: on a small scale, it can blow very hard due to a channelling effect, be absent or very gusty (Lenzholer, 2015). Moreover, cities are often much warmer; normally the difference between urban environments and the surrounding countryside is in between 1 and 10 °C. The increasing temperature in the city has also been addressed by the Municipality of Arnhem (Figure 10). The area in which the Transformatorplein is located has been categorised as an area that urgently needs preventive measures to be taken to reduce heat stress.

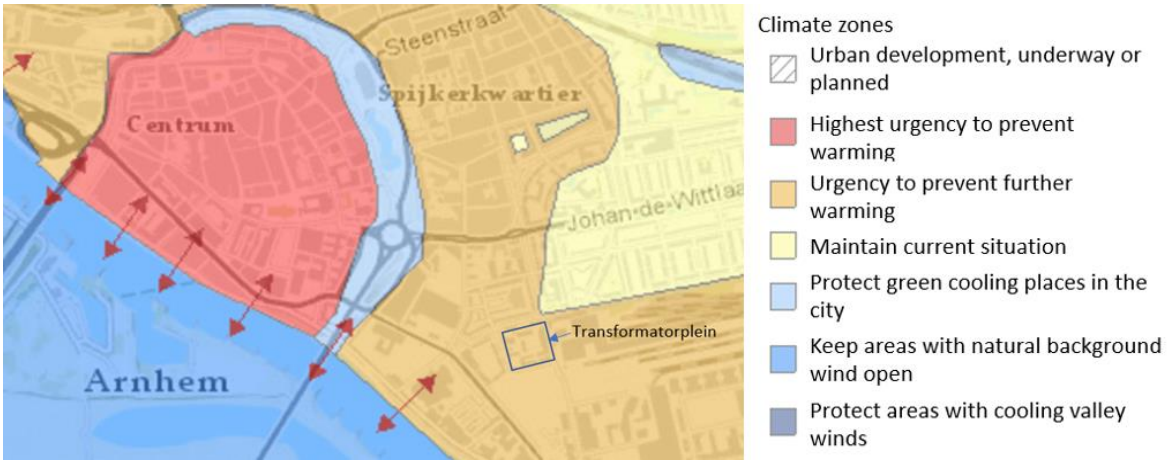


Figure 10 - Climate adaptation map of Arnhem showing that the Transformatorplein is located in an area where further climatic warming needs to be prevented. (Gemeente Arnhem, n.d.).

Both temperature and wind regime on the Transformatorplein can be changed throughout the implementation of small-scale greening measures. These measures are capable of changing factors influencing the local climate, for example reducing hard wind or through minimising the absorption of solar energy (Lenzholer, 2015). Moreover, the implementation of green spaces or measures can provide many ecosystem services, tackling problems often encountered by citizens in urban areas such as a lack of biodiversity, unpleasant aesthetics, missing recreational opportunities, high noise nuisance, lacking water retention and little privacy (Derkzen et al, 2015; Zhang & Muñoz, 2019).

It is unclear which local greening measures would contribute optimally to the previously mentioned ecosystem services on the Transformatorplein whilst being feasible in regards to the soil and water pollution in the area. Aspects such as the effects on noise, biodiversity, water retention, heat resistance and wind developments, as well as practicalities such as the viability, costs, management and residents' preferences of the possible measures will have to be considered. AGORA will investigate which greening measures would change the square, currently perceived as an unattractive concrete jungle, into an urban green space influencing the aforementioned ecosystem services and practicalities positively.

This report encompasses the problem description and objectives, research questions, and a methodology. It continues with an analysis of the current situation and its problems, investigates the opinions of the GTA and the café owner through a questionnaire, proposes potential measures and discusses feasibility aspects for the measures as well as the provided ecosystem services of each measure. Finally, the report provides a scenario analysis for combinations of different measures. The report concludes with a discussion as well as recommendations and conclusions.

3 OBJECTIVE

The objective of this report is to deliver a clear and thorough vision regarding different feasible greening options for restructuring the Transformatorplein in Arnhem into an urban green space. This transformation of the square is supposed to fulfil the previously mentioned ecosystem services and the preferences of the residents involved. By selecting several future scenarios, AGORA will outline the potential greening measures that can be integrated on the square as well as the effects it would have on the Transformatorplein. The report will provide the foundation of the final products, a short leaflet and a poster, both written in Dutch, which will serve as input for the residents to forward the ideas and scenarios to the municipality of Arnhem and the neighbourhood.

4 Research Questions

This section describes the research questions that have been formulated in order to give advice on the feasible and most suitable greening measures on the Transformatorplein.

MAIN QUESTION

Which feasible greening measures are advisable to the GTA initiative to increase the provision of ecosystem services at the Transformatorplein?

SUB-QUESTIONS

1. What is the current situation on the Transformatorplein regarding environmental issues?

2. Which greening measures can be taken to improve the ecosystem services on the square?
   - 2.1. What is the potential of ecosystem services to positively affect the square?
   - 2.2. What are promising greening measures that can be used to enhance the provision of ecosystem services on the square?

3. What are the priorities of the GTA and the café owner regarding the ecosystem services of the Transformatorplein?

4. How could the implementation of different combinations of measures affect ecosystem services provision on the square in the coming five years?
   - 4.1. Which scenarios can be chosen based on the current situation, the identified measures and the needs of the GTA and the café owner?
   - 4.2. Which measures will be considered on the square for each of the scenarios?
   - 4.3. How will different scenarios play out over a course of five years?

5 Methods & Theoretical Frameworks

In this section, the analysis tools that were selected to conduct the research around the transformation of the Transformatorplein are presented and explained.

For the first sub-question, a landscape analysis is described that intends to lay out a clear overview of the current situation at the Transformatorplein. Next, the Ecosystem Services Analysis (ESA) tool is explained. The ESA is performed to answer sub-question 2. Following that, a questionnaire that was sent out to the residents and the café owner is discussed. This questionnaire is used to address sub-question 3 and analyses the different viewpoints and wishes of the residents and the café owner. Finally, an explanation of the Scenario Analysis is provided which will allow answering sub-question 4 with the data obtained from both the ESA tool and the results from the questionnaire. Data for the successful application of the analysis is gathered through literature research. Table 1 gives an overview over the analysis tool used per sub-question.

Table 1 - Table illustrating which method and theoretical framework correspond to which sub-question.

Analysis tool	Related sub-question
Landscape Analysis	1
Ecosystem Service Analysis	2
Questionnaire	3
Scenario Analysis	4

5.1 Method & Theoretical Framework I: Landscape Analysis

The landscape analysis is an examination of the current situation of environmental factors playing a part at the Transformatorplein. The term landscape refers to an area whose features represent the result of interactions between natural and human elements (Medeiros et al., 2016). Urban landscapes represent complex systems that require an integrated analysis approach to fully understand what their characteristics are, what the damages and impacts of anthropogenic activities on urban natural elements are, and how to effectively intervene with suitable measures for their environmental-quality improvement (Hay et al., 2001). In this context, landscape analysis is a technique that incorporates a set of methods and procedures for understanding and explaining the physical and environmental structure and properties of the land that are influenced by uses of the land itself (Medeiros et al., 2016). This landscape approach integrates phases of evaluation and assessment of the considered urban landscape through the analysis and mapping of the environmental characteristics and related problem areas regarding heat, wind, noise, soil, water and the potential provision of urban ecosystem services. Therefore, the landscape analysis applied in this study is used to analyse and assess the different (environmental) factors and layers that need to be considered in rethinking the design of the square (Medeiros et al., 2016). In this project, the urban landscape in particular at the Transformatorplein represents the object of the analysis because it reflects anthropogenic pressures such as the high density of the built environment, large extension of paved surfaces and fragmentation of natural elements that need to be addressed if the quality of the square is to be improved from an environmental point of view (Medeiros et al., 2016).

Here, the aforementioned environmental issues expected on the square are taken into account as well as the movement of people. The analysis will first focus on problem areas on the square to be able to identify causes and solutions. This makes it possible to understand the feasibility of measures as well as the potential of handling problem zones on the square through the selection and configuration of the measures. Environmental factors, considered most influential on the square regarding the climatical experience and influencing the feasibility of measures will be evaluated. These include temperature, wind, noise, water and soil pollution. Additionally, the people flow on the square will be recorded to understand how people currently use the square; this will indicate the current functionality as well as the used areas.

Heat issues on the square will be evaluated through extensive literature research into existing data of heat stress on the Transformatorplein. Moreover, the types of surface materials, as well as the set-up of the buildings on the square, will be mapped and their effect on temperatures will be assessed by consulting the book 'Weather in the City' by Lenzholer (2015). The outcome of this part of the analysis

will make it clear how the used surface materials and configuration of the buildings influence the sensational temperature, and existing maps will provide insights into the heat stress recorded.

To estimate the wind regime playing a part on the Transformatorplein an 'Educated Guess' (Lenzholer, 2015) will be made. By evaluating how the prevailing wind direction reaches the square, one can estimate where the wind will be specifically strong or turbulent. By estimating the height of buildings versus the width of the square over which the prevailing wind is blowing, one can determine the dominant wind regime and estimate in which areas wind nuisance is expected. An 'Educated Guess' can provide background information and help to make choices on potential measures and their configuration on the square.

Extensive literature research and evaluation is conducted to provide scientific insights and background information for the noise, water and soil problems. This will clarify how these aspects play a part on the square and in which manner these should be taken into consideration during the proposal of measures. Moreover, an estimation will be made of how precipitation moves over the square by looking at the ditches, groundwater flow, the slope of the area, and surface type.

The movement of people over the square will be observed with two people for one and a half hours around midday and drawn on a map. It should be noted that this method will only give an idea of the people's flow on the Transformatorplein; additional analysis is needed to give an absolutely certain outcome (Lenzholer, 2015).

5.2 Method & Theoretical Framework II: Ecosystem Services Analysis (ESA)

The concept of ecosystem services is essentially based on the need to emphasise the importance of the role played by nature components and processes in relation to human societies, which are strongly dependent on them (Burkhard et al., 2009). The concept of human health and well-being, especially in anthropogenic environments such as cities, is linked to this concept (McPhearson et al., 2015). Being able to understand how the natural components work in an urban context makes it possible to adapt greening measures for the creation of sustainable and regenerative cities. For the purpose of reducing the impact of the built environment on natural components, one strategy is to integrate the concept of ecosystem services into urban renovation projects (Zari, 2019). Analysing ecosystem services allows exploring the potential they have in improving the quality of the urban environment and its resilience (Gómez-Baggethun et al., 2013). With this objective, an ESA helps to intervene in a more appropriate way through greening measures.

In urban ecosystems, elements of vegetation and water found in or near the built environment play an essential role in providing ecosystem services at different spatial levels, starting from a single building, street or square to the whole city. In this sense, urban ecosystems are particularly important because of the positive impacts the ecosystem services provide for the well-being of the people living in these areas (Gómez-Baggethun et al., 2013). Through the Ecosystem Services Analysis, it will be possible to assess which ecosystem services the square could further support or generate through the implementation of appropriate greening measures (Zari, 2019).

The first step is to provide a general description of the ecosystem services usually provided in urban environments. This general description is specified in this methodology section. Then, the potential of selected ecosystem services on the Transformatorplein will be analysed in more detail in section 8.2.1. The ecosystem services analysis will be followed by the identification of measures that can exploit the

potential of the selected ecosystem services and enhance their provision on the Transformatorplein. In order to clearly consider and communicate the ecosystem services examined in this study, their description and categorisation are necessary. In the literature, different classification categories have been developed, but that of the Millennium Ecosystem Assessment (2003), which includes provisioning services, supporting services, regulating services, and cultural services, is the most widely accepted in academia. However, based on the categories and lists of ecosystem services developed and provided by Costanza et al. (1997), de Groot et al. (2002), the Millennium Ecosystem Assessment (MEA, 2003), Hein et al. (2006) and Zhang & Muñoz (2019), this report will use a categorisation that best fits the aims of the project. This categorisation divides the ecosystem services into the following four main categories:

- **Provisioning services:** natural resources obtained from ecosystems. This includes products such as freshwater, fibre, fuelwood and food that ecosystems provide, and which humans consume. In an urban environment, this can possibly include food provided by activities like urban agriculture on rooftops or in private and community gardens (Kabisch et al., 2017; MEA, 2003; Zhang & Muñoz, 2019).
- **Regulating services:** benefits obtained from the capacity of ecosystems to regulate essential ecological processes influencing climate, hydrological, and biochemical cycles, earth surface and biological dynamics. In urban environments, this includes services such as the regulation of temperature by vegetation and its biological processes like evapotranspiration (Kabisch et al., 2017; MEA, 2003; Zhang & Muñoz, 2019).
- **Cultural services:** nonmaterial benefits obtained from spiritual experiences, aesthetic enjoyment, cognitive development, and recreation often contributing to the natural identity of a place. In urban areas, recreational and aesthetic aspects represent perhaps the most perceivable benefits for the people who live there. These services are provided by urban green infrastructures such as parks and other public and private green spaces (Kabisch et al., 2017; MEA, 2003; Zhang & Muñoz, 2019).
- **Habitat services:** benefits that play an essential role in ensuring the maintenance of ecological processes. These services ensure the provision of suitable living spaces for (urban) biodiversity (Zhang & Muñoz, 2019).

Table 2 presents the description of the main ecosystem services generally provided by natural elements in an urban environment and their categorisation.

Table 2 - Ecosystem services and pertained categories in relation to the urban environment (adapted from Kabisch et al., 2017; MEA, 2003; Zhang & Muñoz, 2019).

Ecosystem Services	Definition
Provisioning services	
Food	Provision of edible product for society (e.g. crops).
Water	Availability of freshwater for different uses.
Ornamental resources	Provision of wild plants for ornamental, aesthetic, and decoration purposes.
Regulating services	
Wind regulation	The function of the vegetation to influence the wind speed and direction by acting as a windbreak.
Air quality regulation	Improvement of air quality due to vegetation processes.
Water retention and regulation	Regulation of runoff and water storage.
Temperature regulation	Natural ecosystems' capacity to regulate and lower the temperature. In urban environments, this service makes it possible to alleviate the heat island effect.
Noise reduction	The ability of ecosystem elements such as trees, bushes and more generally green (urban) infrastructure to mitigate noise impacts.
Cultural services	
Aesthetic	Attractive natural elements that provide enjoyment and aesthetic pleasure.
Recreation	Provision of urban green spaces suitable for a range of recreational activities.
Privacy	Presence of natural elements such as trees and dense vegetation barriers that allow greater privacy in urban public spaces (e.g. for the windows of buildings overlooking such areas).
Habitat services	
Habitat provision	Provision of suitable living spaces for wild plants and animals, allowing urban biodiversity maintenance.

Starting from this general list of ecosystem services, a more detailed analysis will be provided concerning a more restricted list of ecosystem services. This list, which will be analysed in the Ecosystem Services Analysis in section 8.2.1, includes:

- Wind regulation
- Water retention and regulation
- Temperature regulation
- Noise reduction
- Aesthetics, recreation
- Privacy
- Habitat provision

These are the ecosystem services which, as explained in section 4 (problem description), better reflect the needs and the problems perceived at the Transformatorplein. Therefore, all the following sections of the report will be conducted considering this simplified list of ecosystem services.

5.3 Method & Theoretical Framework III: Questionnaire

A questionnaire consists of a list of questions and has the aim to collect information about the objectives of a study. For this study, a formal standardised questionnaire was used, because the data needed to be analysed statistically afterwards (Pushpanjali, Piddennavar, & Malu, 2011). For constructing a questionnaire, it is important to use simple language rather than expertise language, to ensure that the respondents understand the questionnaire (Converse & Presser, 2011). Furthermore, there are specific steps for constructing a questionnaire. First, the key variables must be listed, which for this questionnaire were the function of the respondents, the selected ecosystem services, and the willingness of respondents to help with maintenance or gardening. Secondly, the required information for the questionnaire must be decided on. After that, the order of the questions must be determined, this must flow logically. Next, the types of questions must be determined, i.e. open or closed questions. Lastly, the presentation of the questionnaire is important (Pushpanjali et al., 2011). When deciding on questions, it is important to remember that specific questions are preferred over general questions (Converse & Presser, 2011).

During a preliminary site visit, informal interviews were held with multiple people at the square, amongst which were residents, some artists, and the café owner. It became clear that they all had different viewpoints and priorities regarding the greening of the square. Therefore, it was determined to carry out a formal standardised questionnaire with a selected group of people to get a clear idea about the ranking of perceived problems at the square. This questionnaire was sent out to the GTA and the café owner. The GTA did not want too many different inputs, which is why the questionnaire was not sent to for example the artists or the municipality. Further elaboration on this and the limitations can be found in section 9.

The questionnaire takes the function of the respondent into account, i.e. house owner, renter, or café owner. The respondents were asked to distribute 100 points among eight different factors:

- An increase in privacy for residents and users of the square
- An improvement of the acoustics on the square
- A decrease of extreme heat on warm days
- An improved water balance, so less drought and not too much water on the square

- A decrease of strong winds over the square
- More attention to the aesthetics of the square
- More attention to functionality (recreation, sports opportunities, places to sit, etc.)
- An increase in biodiversity, so more plant and animal species

This allowed for an analysis to see which aspects were most important and which needed the most focus on improving. Furthermore, a question was included to get a view of the willingness of the respondents in helping with the maintenance and gardening of the square after the implementation of the measures. Each house had the same influence, therefore the weights were altered accordingly if there were multiple responses from one house.

For the full list of questions in the questionnaire, please see Appendix 12.1.

5.4 Method & Theoretical Framework IV: Scenario Analysis

The evolution of various environmental problems has to do with the very future of the environment. For this reason, projects that involve environmental assessment typically must cover both the current and the future state of the environment (Alcamo, 2001). In this study, the focus is on improving the ability to cope with climate change and the environmental quality of the Transformatorplein. The achievement of these objectives is possible through the implementation of greening measures designed to reduce the increasing environmental stresses and pressures caused by the built environment and climate change. Therefore, it is essential to assess how such measures can help in the shift from the current state to a condition in which the increase of the ecosystem services provision leads to a climate-proof square. To evaluate and describe something that will potentially happen in the future and that needs a period of time to develop (Alcamo, 2001), there is a need to construct scenarios of the future. As described by the Intergovernmental Panel on Climate Change (IPCC), scenarios represent alternative future developments that are neither predictions nor forecasts, but alternative delineations of how the future might unfold (Nakićenović et al., 2000). Generally, there are several types of scenarios, such as climate or pollution scenarios. However, in this study, the focus will be on the development of different future scenarios of the Transformatorplein based on the ecosystem services (benefits) that different greening measures may provide over time.

Some of the principal elements of a scenario analysis are:

- **Description of stepwise changes.** Step-by-step representation of gradual changes in the study area in the future. These changes can be given in the form of a table (Alcamo, 2001; Raskin et al., 2002).
- **Driving forces.** Drivers are the main factors leading to the changes described in a scenario (Alcamo, 2001; Raskin et al., 2002). In the case of this report, the driving forces for the change of the Transformatorplein are represented by a combination of aspects. They include the policies and regulations that apply, environmental awareness as well as the commissioners' and stakeholders' willingness and financial capacity to change.
- **Geographic coverage.** The geographic coverage represents the spatial dimension considered in the scenarios (Alcamo, 2001). In this case, the area of interest is the Transformatorplein and possibly the surrounding areas that could be affected once certain greening measures have been implemented or are affecting the Transformatorplein (through, for instance, the heat island effect).

- **Base year.** The base year represents the year from which every scenario starts (Alcamo, 2001). Therefore, the base year, in this case, is 2020, the year when the present study and analysis are conducted.
- **Time horizon and time steps.** The most distant future year still included in the scenario represents the time horizon (Alcamo, 2001). In this study, the time horizon is represented by the year 2025. Usually, the number of the time steps between the base year and the time horizon of the scenarios is kept to a minimum considering the detail required to provide a complete description of the development of each scenario (Alcamo, 2001). Considering that this study is focusing on a rather short-term period of five years, the progression is represented by a single time step, fixed at the end of the considered period, i.e. after five years, in 2025. Consequently, the current situation of the square and the situation in 2025 will be described for each scenario, always considering the different greening measures potentially implemented.
- **Storyline.** Each scenario will be presented in the form of a narrative description, linking all the above-mentioned elements (Alcamo, 2001; Raskin et al., 2002).

The delineation of the different scenarios in the form of stories allows the communication of the results in a comprehensible way (Alcamo, 2001). This helps in presenting the material to the municipality for transformation approval. The first scenario will be used to provide a picture of the future state of the study area in the absence of any interventions (Alcamo, 2001), called the Paved Future scenario. By providing a baseline scenario, it is possible to provide a visual and descriptive analysis of the impact that the implementation of different greening measures can have on the resilience and climate-proof improvement of the Transformatorplein. The scenario analysis constitutes a tool to illustrate how alternative sustainable intervention pathways can contribute to achieving an improvement of the urban environment quality (Alcamo, 2001; Raskin et al., 2002).

The scenario-building will be based on the outcomes of the questionnaire (section 7.3), the functionality of the square, climate resilience and the potential complications on the location. With this input, four different scenarios (including a baseline) will be developed and evaluated. In this report, the Scenario Analysis is constructed taking into account a time range of five years. This choice is not strictly based on a review of the scientific literature but rather on a subjective choice of the research and analysis modality of the consultancy group. The reason for this choice is represented by the fact that the consideration of a shorter time range allows providing a more realistic and concrete description of what will be the outcomes and evolution in terms of ecosystem services provision of the different scenarios. Moreover, since the green transformation of the Transformatorplein is a project that involves the residents who were first interested in the possible improvement of the environmental quality of the square, it was deemed appropriate to select a time range that allows a short-term visualisation of changes and improvements.

6 Results

6.1 Analysing the Landscape

This section will describe the Landscape Analysis conducted; it will evaluate and visualise environmental factors playing a part on the Transformatorplein as well as describe how people move over and use the square. The results of this analysis will help in answering the first subquestion.

6.1.1 Heat

Temperature issues on the square are expected due to the urban heat island effect (Lenzholer, 2015). The climatic experience of people is mainly determined by both the sensation of temperature, thus the temperature in a specific location as well as the effect the environment has on the perceived experience and wind effects (Lenzholer, 2015). In terms of heat, there are two different types of temperatures, the actual temperature and the experienced temperature by humans. The experienced temperature is dependent on two factors: (1) the actual air temperature, which is influenced by different environmental factors; and (2) the personally perceived temperature, which is highly bound to an individuals' perception. The personal experience of temperature is for example influenced by the openness of space, the materials used and the associations made with it, cultural background and the colours of the surrounding landscape (Lenzholer, 2015).

The local map of the Transformatorplein (Figure 11) shows outcomes indicating heat stress on the square: the personal experience of temperatures on a hot summer day can feel like 39-42°C. Especially at night, the heat island (UHI) effect of the city centre nearby also increases the actual temperatures on the square by about 1.4-1.6°C on a yearly average (Atlas Natuurlijk Kapitaal, n.d.). In the summer months, the urban heat island effect can increase the actual temperatures much more severely. Furthermore, the emission of anthropogenic heat increases with higher energy consumption, for example, energy used for heating or cooling, and thus amplifies the urban heat island effect even more (Yuan, 2018). The large trees to both sides of the road on the Broekstraat (10-15 metres tall) just north of the Transformatorplein and the smaller trees on the eastern Van Oldenbarneveldtstraat (5-10 metres tall) seem to cool the experienced temperature down to 31-33°C thus providing a cooling effect of almost 9°C (Figure 11). This is a clear indication that greening measures could decrease the personal experience of temperature.

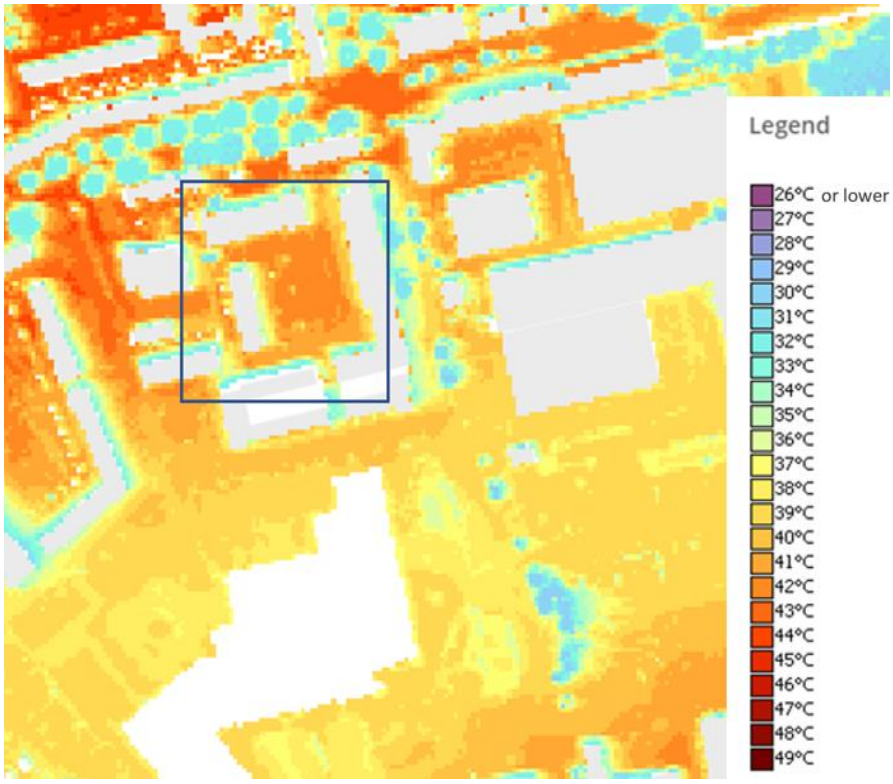


Figure 11 - Experienced temperature at the Transformatorplein on a hot summer day with a maximum reaching 39-42°C (Atlas Natuurlijk Kapitaal, n.d.).

The actual air temperature on the square gets hot partly due to its many paved surfaces and dark colours. A large amount of heat can be stored in these surfaces during the day, and this will continue to warm the atmosphere during both day and night (Breuste et al., 1998; Lenzholer, 2015). In Figure 12 and Figure 13, it is visible that a large proportion of the square consists of materials inducing heat stress on the square. Many of the surfaces on the square consist of dark coloured bricks and dark roofs. These materials will absorb heat and release it to the environment. Thus, the usage of these materials will increase the temperatures in the square. This will especially take place on hot summer days when solar radiation is heating the surface areas. On the other hand, urban green spaces will cool the actual air temperature; this is also visible in Figure 12 and Figure 13 (Lenzholzer, 2015).
In urban environments, the configuration of buildings also plays part in the high temperatures. Solar radiation becomes trapped in narrow streets and therefore, cooling takes longer. Because the Transformatorplein is a large square, this effect is considered of less significance than the surface materials (Lenzholer, 2015).

Concluding, the building surfaces used on the Transformatorplein contribute to a higher temperature both due to the warm colours as well as the material. The experienced temperature on the square can be very high on a hot summer day.

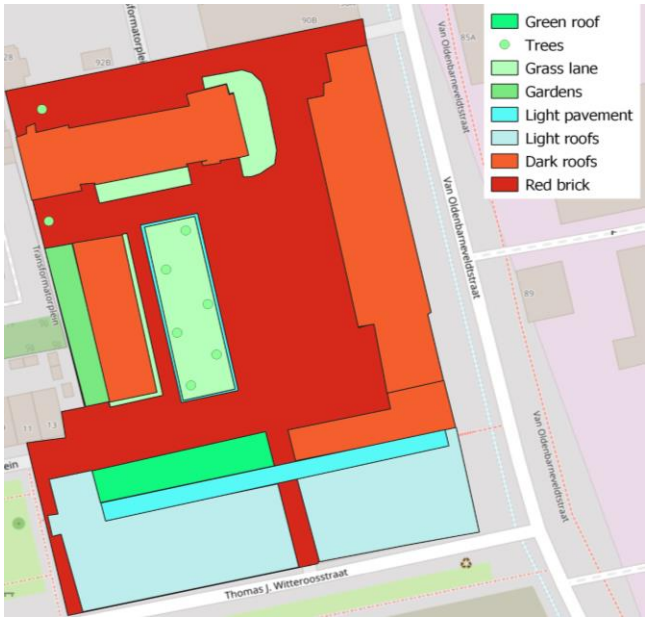


Figure 13 - Main surface materials used on the Transformatorplein, including red bricks, dark roofs and grass lanes.

Figure 12 - Aerial view of the surfaces on the Transformatorplein, including paved surfaces, exposed soil and dark rooftops (print screen Transformatorplein from Google Maps, captured one 10th of October 2020).

6.1.2 Wind

The prevailing wind in Arnhem is coming from the southwest and blows towards the northeast (Figure 14). For the Transformatorplein this means that the prevailing wind is blowing over the square as indicated in Figure 14.

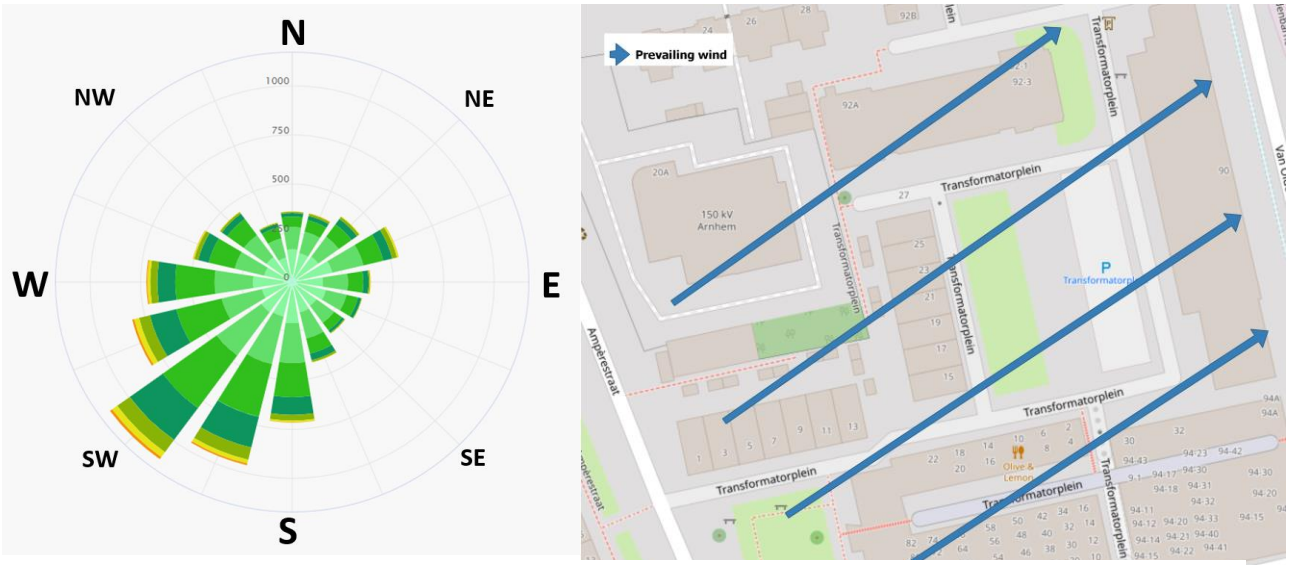


Figure 14 - The prevailing wind direction in Arnhem and on the Transformatorplein is from the southwest to the northeast (Meteoblue, n.d.).

The built environment has large effects on the local winds. An 'Educated Guess' has been conducted to estimate the wind regime on the square on days with a southwestern wind. This has been done to evaluate the problem zones according to Lenzholer (2015). A visualisation of the estimated wind regime has been given in Figure 15.

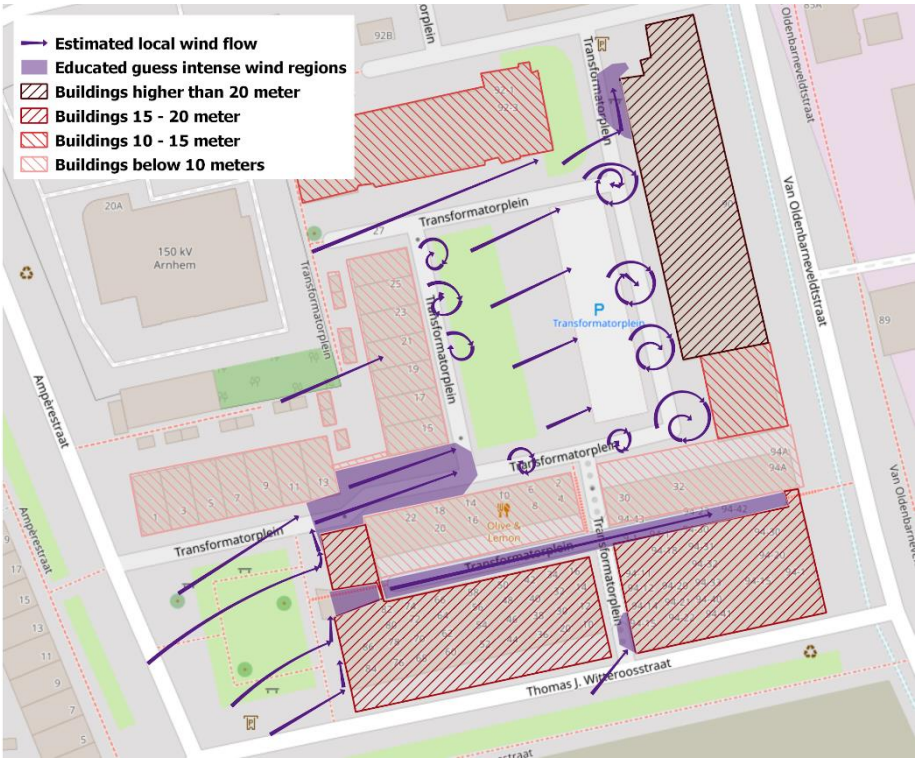


Figure 15 - Visualisation of the 'Educated Guess' (Lenzholer, 2015) regarding the wind regime on the Transformatorplein showing areas of intense and local wind flows.

The wind is reaching the square from the southwest and will reach the high buildings in the lower-left corner of Figure 15. Consequently, the wind will be compressed and move through the narrow streets and allies. In these locations, the wind is expected to increase significantly in strength and may lead to wind nuisance. Moreover, the wind coming down from the tall buildings will form currents on the northeastern side (of the square). From the southwest, the wind reaches the houses of the residents of house numbers 15 - 27, which are estimated to be less than 10 metres tall. According to Lenzholer (2015), a height/width ratio lower than 0.3 will lead to an *isolated roughness flow* which is the cause of wind nuisance on large squares. The width of the square (from the residential building block to the monumental building) is estimated to be more than 40 metres, and therefore the height/width ratio is lower than 0.3. The *isolated roughness flow* indicates that the wind will drop towards the square after passing over the residential building, thus creating currents in front of the buildings as well as strong winds blowing over the square. Moreover, the wind will hit the monumental building on the eastern side of the square; possibly even stronger turbulent wind is expected to occur here. On the corner of the monumental building on the northeastern side of the square, the wind is pushed against the tall building and will move towards the building. The compression of wind will again result in an intense wind region.

Interpreting the 'Educated Guess', it is clear that most of the year, on windy days, there will be wind nuisance on the square due to the i*solated roughness flow* regime. Problem areas can mainly be found in the narrow street in the southwestern corner; moreover, turbulent wind can be found near the residents' building and the monumental building.

6.1.3 Noise

There is an average noise level of about 55-65 decibel with some noise pollution from the western street nearby (Westervoortsedijk) and the industrial area to the East (Figure 16). Depending on the direction of the wind, these areas can influence the noise pollution on the square, which can rise up to 75 decibels. Furthermore, the café and the nearby gym can add to noise pollution as they attract people. A large proportion of the building materials (Figure 12 and Figure 13) will echo the sounds produced on - and around - the square (Derkzen et al., 2015) and therefore the surfaces on the square contribute to the noise pollution.

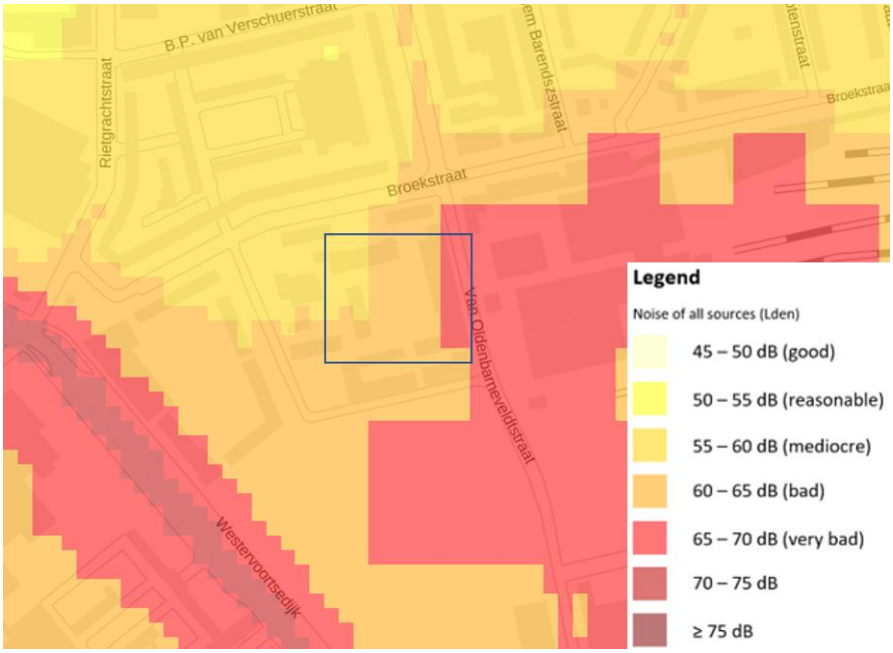


Figure 16 - Average noise levels on the Transformatorplein range from 50dB to 70dB (Atlas Leefomgeving, n.d.).

6.1.4 Soil

The former gas factory, located in the area of the Transformatorplein from 1860 to approximately 1960, caused significant soil and groundwater pollution. Within the limits of soil contamination, intervention values were exceeded for the following substances in 1996: cyanide, PAH (polycyclic aromatic hydrocarbons), tar-like compounds, lead and mineral oil (Provincie Gelderland, 1996). These pollutants have varying levels of toxicity for flora and fauna. Cyanide generally has little effect on fauna due to low uptake of cyanide by plants (Hegger, 2009). The cyanide polluted soil can impact the quality of the air, is dangerous when consumed by children (e.g. in a playground) and can also be measured by the concentration in groundwater in the soil pores. Unlike cyanide, PAH pollution in soils may affect plant germination and growth in the case of volatile, water-soluble low molecular-weight hydrocarbons (<3 rings). High molecular weight PAH (3+ rings) have not shown any effect on growth and germination (Henner et al., 1999). Soil pollution of lead has adverse effects on germination and growth (Pourrut et al., 2011). Lead uptake accumulates in roots of plants and may cause swollen, bent, short and stubby roots. Lead exposure may also result in lower plant biomass. Lead regulations are based on the risk for children, as children are more sensitive to lead and take up lead more efficiently than adults do (Hegger et al, 2009).

Remediation of the soil in the area of the Transformatorplein has already been done in 1992. At the time, the top 2-4 metres of soil was replaced with clean sand (Heidemij Advies, 1993). Due to this remediation

the soil in the area gained the following composition as measured in 1996 (Provincie Gelderland, 1996) and was confirmed for the top 8 metres of soil in the report of MWH (2012):

- 0 - approx. 4m sandy top layer (fine to coarse to very strong loamy sand, placed in 1992)
- 4 - approx. 7m clay (old soil)
- 7 - 45m first aquifer package
- 45 - 51m clay layer (not present everywhere)
- > 51m second aquifer package

Later measurements in 2012 showed the previously mentioned soil pollution was mostly remedied while there was still significant pollution in the groundwater present in the area of the Transformatorplein (MWH, 2012). The destination plan of the municipality of Arnhem to transform the area of the Westervoortsedijk West from an industrial area into a residential area meant that the soil was subject to new regulations. To meet the standards for residential areas, the commissioners mentioned that the first top metre of the soil was remediated before the residential houses were built (S. van Vliet, personal communication, October 7, 2020). Removing 50 cm of soil for the transformation of Zone 1 in front of the residential houses showed that the top layer of soil under the pavement now consists of 10 cm of fine yellow sand commonly used underneath the brick pavement. Underneath this sand is 30 to 50 cm of almost solid stone rubble. The first metre of the soil found during the new remediation has been visualised in Figure 11.

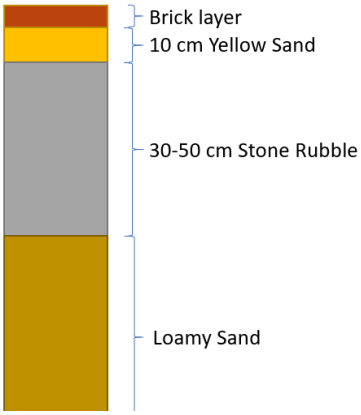


Figure 17 - Top layer of the soil on the Transformatorplein in front of resident's houses as found during the remediation of the front gardens.

Existence of the rubble layer was confirmed by the municipality as a stabilisation layer for the pavement above (H. Velthorst, Personal communication, October 9, 2020). It is assumed that the rubble layer was not placed under the green area in the centre of the square as that area was developed prior.

In the areas of the rubble layer, there is presumably a separation layer around 1-1.5 metre(s) underneath the ground surface (H. Velthorst, Personal communication, October 9, 2020). This separation layer, consisting of a tarp, is meant as a physical boundary for animals living in the soil, such as worms and moles, to prevent active soil mixing. The tarp is permeable to allow groundwater to flow through. To prevent water from coming up when there is a high phreatic pressure due to a high water level of the Rhine or high water supply from the floodplains, a drainage system is in place either above or below the separation layer. This separation layer prevents the polluted groundwater below the separation layer from reaching the cleaner groundwater above the separation layer (H. Velthorst, Personal communication, October 9, 2020).

Soil pollution for the area of Westervoortsedijk has been visualised by the municipality of Arnhem (Figure 18). A distinction between the still polluted areas of the Westervoortsedijk and the remediated soil of the Transformatorplein can be seen.

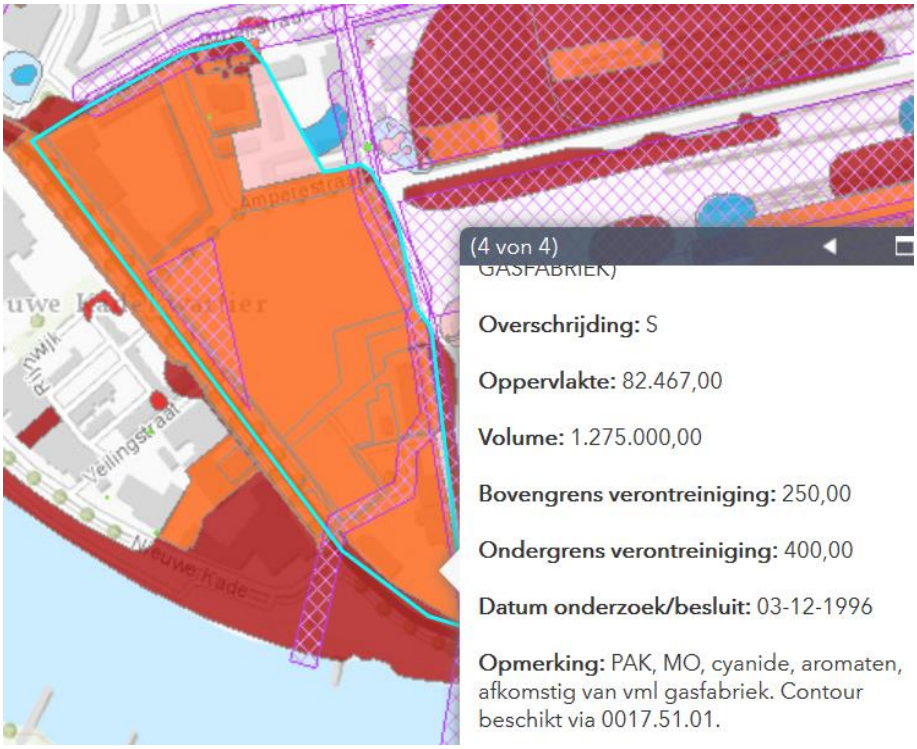


Figure 18 - Different soil pollution levels are present in the area around the Transformatorplein showing traces of cyanide a.o. (Bodeminformatie Gemeente Arnhem, n.d.).

An additional environmental factor that should be taken into consideration is the compound "juglone" produced by the walnut trees in Zone 2. The walnut trees on the square most likely identify as the species *Juglans Regia,* which is prominent in Europe (McGranahan & Leslie, 2009) and is known to produce the water-soluble yellow pigment juglone (Seigler, 1998). Hydrojuglone is found in the tree's leaves and walnut shells and oxidises to juglone when exposed to oxygen. Juglone can work as a toxic inhibitor to many seeds, plants and insects when the leaves and husks fall to the ground and leak into the soil (Seigler, 1998). Therefore, plant growth near walnut trees could be restricted.

Concluding, the soil underneath the Transformatorplein is highly influenced by its industrial past. Even though remediation has taken place, groundwater is still polluted and this needs to be taken into consideration. Moreover, the soil is expected to be sandy and space limited, due to the impermeable layer as well as the rubble layer used in some locations.

6.1.5 Water

According to a report by the Province of Gelderland (Provincie Gelderland, 1996), the phreatic groundwater at the Transformatorplein in Arnhem is at a depth of 2.3 - 3 metres below the surface. The phreatic groundwater generally flows off all sides in that area, however, the direction of flow of the groundwater in the aquifer is predominantly southwestern towards the nearby Rhine river as visible in Figure 19. In case of very high water levels of the Rhine, this direction of flow may be reversed temporarily (Provincie Gelderland, 1996), but in such cases, the drainage system under the square prevents water from reaching the upper 1.5 metres of the soil layer. In groundwater, intervention values were exceeded for the following substances: cyanide, aromatics, PAH (polycyclic aromatic hydrocarbons) and mineral oil. The amount of contaminated groundwater with concentrations above the intervention values was more than 15,000 m^3 in 1996 (Provincie Gelderland, 1996).

A report from 2012 found that the groundwater on the square (measured through monitoring wells) was now polluted with mainly increased concentrations of VOCl. The results showed that in 2012, the groundwater from some monitoring wells had significantly elevated concentrations (MWH, 2012). The risk of spreading of toxic elements is uncertain since the pollution has not been contained (MWH, 2012).

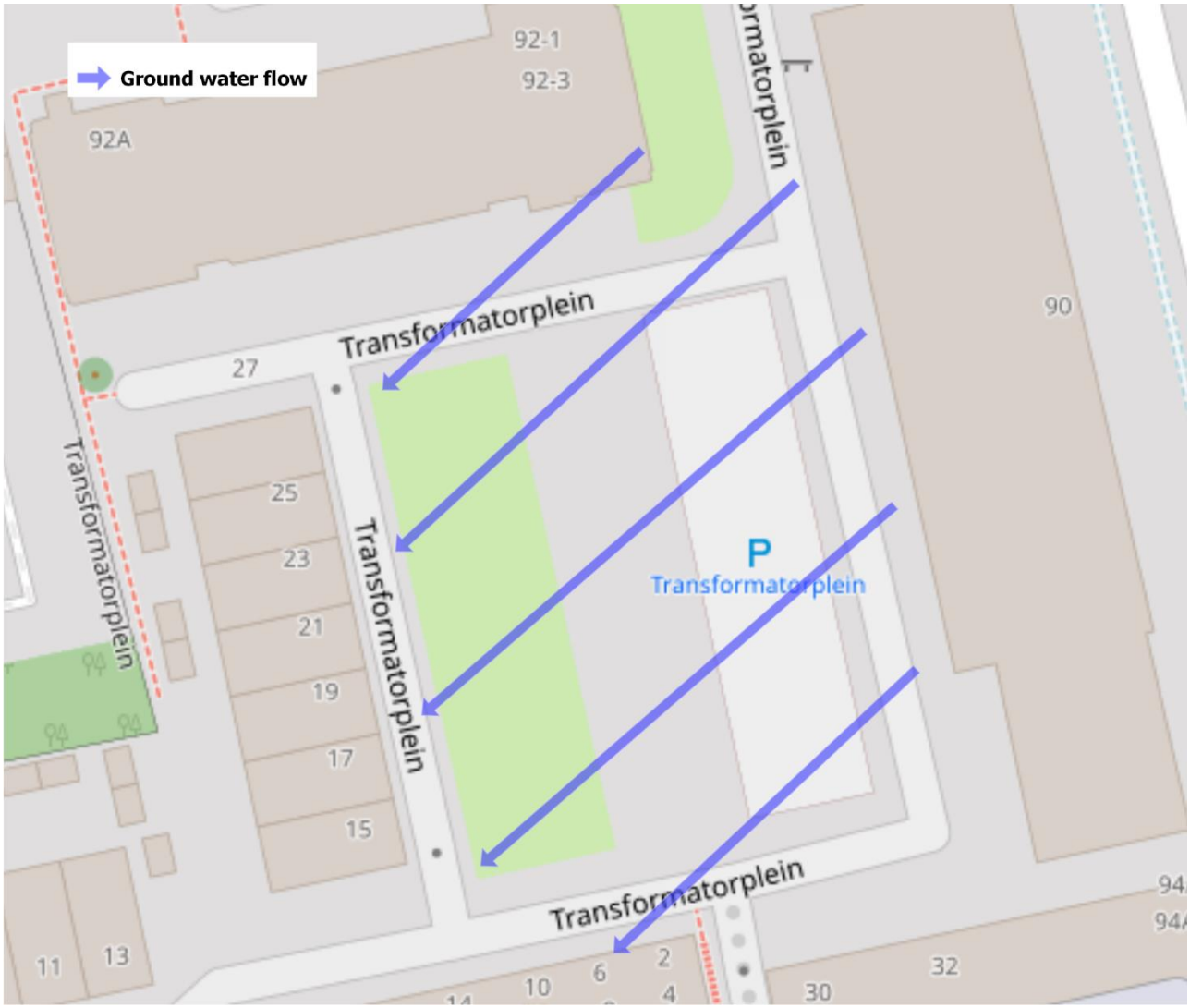


Figure 19 - The direction of the groundwater flow on the Transformatorplein is towards SW.

Precipitation in urban areas can be discharged in several ways (Figure 20). A part will directly infiltrate quickly into the sandy soil and will be led towards surface waters by groundwater flow. This will mainly occur in the vegetated areas, which will easily retain water and let it seep down. Another part is caught on paved surfaces of streets and buildings and will end as runoff, whilst following a slight slope, into surface water via gutters, drains and the sewage system. The last part of the precipitation evaporates, either directly or indirectly. The amount of evaporation is dependent on the vegetation (Meyer et al., 2006). Currently, due to a large amount of paved surface, surface runoff increases whereas groundwater recharge decreases (Zelenakova, Hlavínek, & Negm, 2020).

Figure 20 - A visualisation of precipitation both seeping into groundwater, which mainly occurs on the vegetated areas, and the rainwater running off towards ditches and thus into the sewage systems. The estimation is based on the slight slope present on the square's surface, the surface type (vegetated or not-vegetated) and the presence of ditches.

The water situation at the Transformatorplein indicates that there may not be a lot of flooding in the area. Most of the rainwater will be discharged through the ditches; the slightly sloped surface is contributing to the runoff. Moreover, the green areas may suffer from drought instead. Because of the elevation of these areas in combination with the sandy soil, water is expected to seep fast and the evapotranspiration from the soil will be high.

6.1.6 People Flow

The movement of people on the Transformatorplein has been visualised in Figure 21. Even though this observation is just an indication of how people use the square, it became clear that most people were just crossing the square and during the time frame, no one used it for recreational purposes except for walking their dog. The main routes taken on the square were people moving to the café (Olive & Lemon on the map) or people parking their car. This indicates that, even though the square is used, the recreational function is very low.

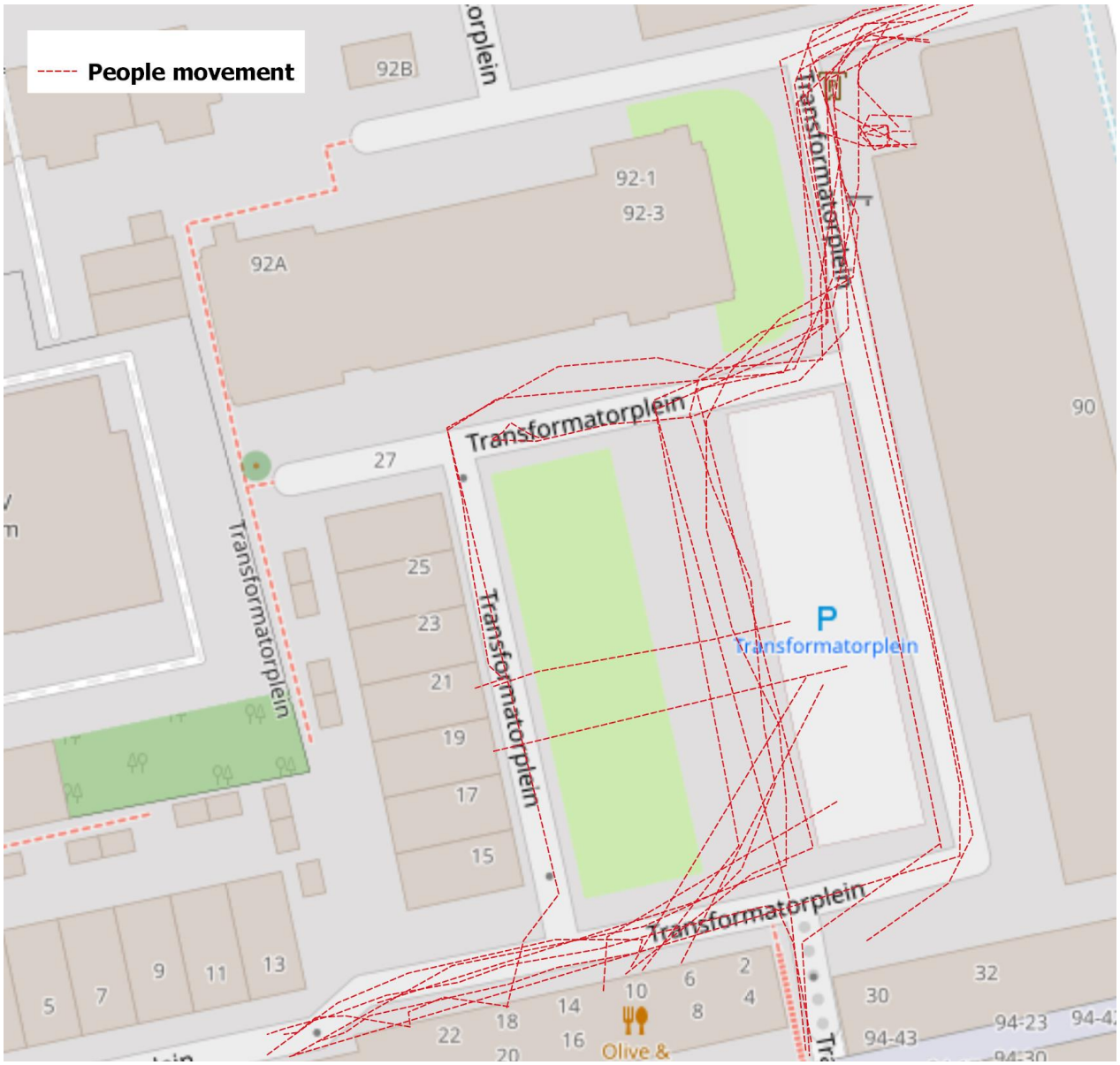


Figure 21 - Reflection on the people flow on the Transformatorplein. The observations were made with two observers on the 1st of October 2020 between 10.30 and 12.00

6.2 Analysing Ecosystem Services and considering Greening Measures

The following results sections present an analysis of ecosystem services and a description of potentially implementable greening measures. Section 8.2.1 consists of a detailed description of the potential of selected ecosystem services and their relationship to the possible improvement of the current condition of the Transformatorplein. Section 8.2.2 consists of an accurate presentation of greening measures that could be implemented in the square to exploit the analysed potential of the selected ecosystem services.

6.2.1 Ecosystem Services Provision

6.2.1.1 Wind regulation

In several studies, it has been proven that in urban environments the wind speed is lowered by 10-30% and the urban natural elements help to make this service even more evident (Bolund & Hunhammar, 1999). In fact, the presence of vegetation in the proximity of dwellings can contribute to a decrease in the energy used for heating by reducing the wind speed during the winter months (Bolund & Hunhammar, 1999). However, in the current situation of the Transformatorlein, the vegetation elements do not have the characteristics to provide this service and moreover, they are not in such a number as to constitute wind barriers. From the observations made in the field by the consultancy group, as shown and described in section 8.1.2 (wind), it can be seen that the wind blows over the square from southwest to northeast without any physical barrier to block it along the square itself. For example, the few walnut trees placed in front of the houses of the residents do not have developed foliage to allow for wind regulation and are the only plant elements currently present in the square with a vertical structure.

6.2.1.2 Water retention and regulation

A considerable amount of paved surfaces in urban environments causes alterations in the flow of water following heavy rain events. Much of this water undergoes surface run-off processes that can cause problems of flooding or further pollution of the water due to the collection of pollutants found in cities (Bolund & Hunhammar, 1999). Besides, paved surfaces can also cause the creation of unintentional water run-off paths, which can lead, for example, to water leaking from sewers. Vegetated areas, with softer soil instead of impermeable surfaces, allow water to infiltrate it first and then for the vegetation to absorb the water and release it into the air through evapotranspiration processes. It is due to these dynamics that in the presence of vegetated surfaces there is a run-off of only 5-15% of rainwater, as opposed to 60% which usually occurs where only paved surfaces appear (Bolund & Hunhammar, 1999). In addition, urban greening measures such as green roofs can retain 25-100% of rainwater depending on their design characteristics (Gómez-Baggethun et al., 2013). At present, as described in section 8.1.5, due to the predominance in the Transformatorplein of paved surfaces, the surface runoff considerably exceeds the groundwater recharge. For this reason, to avoid problems in case of extreme rainfall events, it is useful to enhance and take advantage of the ecosystem service of water regulation that can be provided by vegetated areas.

6.2.1.3 Temperature regulation

Urban vegetation plays a fundamental role in regulating temperature. A single large tree can transpire up to 450 litres of water per day, consuming about 1000 MJ of heat energy to conduct evaporation processes (Bolund & Hunhammar, 1999). In other words, a single tree of decent size can on average

lower the air temperature around it by about 1.2 °C during the hottest hours of the day. Besides, the shade created by a dense canopy can also help to lower the surface temperature of the ground by 5-7 °C, varying with latitudinal characteristics such as the angle of incidence of sunlight (Shahidan, 2015). Vegetation can also reduce the energy used for air conditioning by creating shaded areas near houses during summer periods. In this way, natural elements contribute to counteracting the urban heat island effect, caused by the presence of large paved areas absorbing heat (Bolund & Hunhammar, 1999). The urban heat island effect has been observed and experienced by the commissioners and the inhabitants on and around the Transformatorplein. As described in section 8.1.1, on summer days the square gets hot (39-42 °C) due to the large amounts of paved surfaces. Currently, however, the few walnut trees and the sparse grass-covered areas are not sufficient to tackle the urban heat island effect registered and perceived in the square.

6.2.1.4 Noise reduction

It is known that noise from traffic and other sources causes considerable disturbance and health problems for people living in heavily urbanised areas (Bolund & Hunhammar, 1999). Concerning these problems, it has been observed how soil and plants can mitigate noise pollution through absorption, diversion, and reflection of sound waves (Gómez-Baggethun et al., 2013). The simple presence of a lawn rather than a paved surface contributes to a noise reduction of about 3 decibels. Other types of vegetation can also contribute to the reduction of noise reaching buildings, but the precise level of reduction for different types of vegetation is still uncertain (Bolund & Hunhammar, 1999). Due to the absence of leaves in winter, the attenuation of noise is less in that season. Therefore, better attenuation year-round can be provided by evergreen trees that retain their leaves through all the seasons (Bucur, 2006). It was also found that attenuation of sound by tree trunks increases linearly with an increase in the diameter of the tree trunk (Bucur, 2006). Some studies claim that the presence of fairly wide bushes (about 5 metres) in urban environments can contribute to a noise reduction of about 2-3 decibels (Bolund & Hunhammar, 1999). It has been shown that characteristic vegetation factors that play a key role in reducing noise include height, width, density, length and width of branches and leaves (Gómez-Baggethun et al., 2013). In the Transformatorplein, as shown in section 8.1.3, there is a significant noise disturbance produced by the nearby industrial area and streets. In this sense, the square has great potential for improvement considering that, currently, there are no real natural barriers to noise, there is a predominance of paved surface that facilitates the propagation of sound waves, and the tree canopies of the walnut trees in the square are not yet very developed.

6.2.1.5 Aesthetics

Urban natural elements play an important role in providing psychological benefits through the aesthetic pleasures associated with them. The observation of colourful flowers and wildlife in cities enriches urban public places with meaning and consequent emotions (Gómez-Baggethun et al., 2013). The benefits linked to the aesthetics of urban ecosystems are linked to increased human health (Lee et al., 2015). Furthermore, the proximity of dwellings to natural elements has been linked to stress reduction (Coolen & Meesters, 2012; Gómez-Baggethun et al., 2013). Likewise, people choose to live or spend more time in those areas of the city characterised by more aesthetically attractive natural elements (Gómez-Baggethun et al., 2013). However, currently, the Transformatorplein appears as a bare square characterised by the prevalence of concrete, sealed surfaces and little vegetation. The overall result is the lack of visually attractive elements.

6.2.1.6 Recreation

In urban environments characterised by constant frenzied activities, the recreational aspects linked to the elements of urban nature, which provide an opportunity to play or take a break, represent perhaps the ecosystem service most perceived and appreciated by citizens (Bolund & Hunhammar, 1999; Lee et al., 2015). The possibility of observing elements of biodiversity such as birds and colourful insects in highly anthropogenic areas are also attributable to recreational and educational values. Besides, the proven positive effect that natural elements have on human psychology and the reduction of stress levels is an example of an enormous contribution to the well-being of citizens (Bolund & Hunhammar, 1999; Coolen & Meester, 2012; Lee et al., 2015). In this sense, the Transformatorplein has potential for improvement, since the first elements that appear to be noticeable are paved surfaces and bare surfaces of the buildings that dominate the square.

6.2.1.7 Privacy

Natural elements of urban ecosystems can represent natural barriers: privacy can be provided for example by planting bushes and trees in the proximity of dwellings, windows, and parking lots (Gómez-Baggethun et al., 2013; Zhang & Muñoz, 2019). An open area, like the square considered in this study, is characterised by a lack of privacy for all the people who live there, especially those who have windows overlooking the square. However, at the moment, there are no barriers that could prevent people passing by from directly observing the windows and houses.

6.2.1.8 Habitat provision

In a world where biodiversity, and the animal and plant species it encompasses, are increasingly threatened by a multiplicity of factors, such as pollution, fragmentation of natural habitats and climate change, it is important to consider ways to enhance their survival. In this sense, cities can provide numerous areas of refuge for birds, insects and other wildlife (Gómez-Baggethun et al., 2013). Several elements can play different roles: large deciduous trees can contribute to the movement and support of numerous species of birds with great dispersal capacity; flower fields can support ecological interaction dynamics between insects and birds; green roofs can provide a suitable habitat for those species suffering from the fragmentation of the natural environment attributable to the built environment (Bolund & Hunhammar, 1999). In the Transformatorplein the consultancy group observed the existence of animal flows but the potential for improvement is still high, especially for pollinator species which play a key role in urban ecosystems (Turo & Gardiner, 2019). The Transformatorplein offers the potential to increase the provision of ecosystem services. It is possible to create suitable areas for pollinators (such as bees) to overcome stressors associated with the urban environment.

6.2.2 Greening Measures

The transformation of the Transformatorplein will take place by way of adding greening measures to the different zones of the square. This section provides an overview of measures that would improve the ecosystem services at the Transformatorplein. The measures have been chosen according to the following criteria:

- The measure contributes to at least one of the ecosystem services focussed on (aesthetics, noise reduction, privacy, recreation, temperature regulation, habitat provision, water retention and wind regulation) and preferably to a combination of ecosystem services.

- The measure is implementable concerning the environmental conditions in water regime and soil pollution on the site (discussed in section 8.1) or the required actions before implementation can start are clear and manageable.
- The measure is implementable in the climate of Arnhem.

Each of the measures is presented with a short explanation of the measure, its contribution to ecosystem services, and possible disadvantages. The measures are presented in alphabetical order that in no way represents an order of recommendation.

6.2.2.1 Explanation and Impact of Greening Measures

The different greening measures selected and their contribution of ecosystem services, disadvantages and zone(s) in which they will be placed are shown in Table 3. An in-depth explanation of these measures can be found in Appendix 12.3.


Aesthetics


Financial aspect


Functional use (recreation)


Habitat provision (biodiversity)


Maintenance


Noise reduction


Privacy

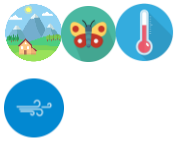

Temperature regulation


Water retention and regulation


Wind regulation

Table 3 - Description of measures, their rated contribution to ecosystem services, and the disadvantages regarding management effort or the financial aspect.

Measure Description	Contribution to Ecosystem Services:	Disad-vantages
Annual/Perennial flower meadows Flower fields placed in Zone 2 and Zone 3 could provide habitat for insects and therefore increase biodiversity. They may also increase the water retention, aesthetics of the square through additional colours, and reduce the heat through evapotranspiration.	 (When planned well) 	
Bird boxes Birdhouses can provide nesting and roosting sites. They make the square more attractive for several cave nesting bird species but need cleaning once in a while.		
Bushes Bushes planted in an area may serve various purposes. They may form a natural wall to offer protection from wind, sound and sight. Like trees, bushes can also provide some form of shade, although this shade will be different from trees since they are lower to the ground. Adding some bushes to an area could also increase the biodiversity due to the possibility of providing shelter and food for animals.		
Free-standing green wall The free-standing structure represents the evolution of the concept of the standard building's green wall. Free-standing green walls can be used in a sitting area (like the café on the Transformatorplein) to provide a wide range of benefits: screen and isolate views, mitigate noise, regulate temperature, break wind and create aesthetically attractive elements.		
Free-standing mini ponds The free-standing mini ponds take up less than 1 m^2 each and are kept in a portable, free-standing container. The ponds can include a few aquatic plants and potentially some wildlife like fish, frogs, snails or salamanders. Depending on the depth, they can also provide a source of water and a bath for birds.		
Green rooftops Rooftops on the square (residential houses, social housing) could potentially be greened to increase the albedo effect and decrease the heat stress on the square. This could also increase the biodiversity of the square. Green rooftops might be tricky to install due to the solar panels present on the residential houses.		

Green roof carport A green roof carport is an infrastructure designed to provide the same benefits as a green roof but combines this idea with that of a structure to provide shade and shelter for cars. In short, it is a carport with vegetation on the roof that allows the creation of habitat for biodiversity, temperature regulation, and water retention. If placed on the square, it could also influence the wind flow.		
Green walls on residential houses Green walls, or facades, could be created with construction botany. Here, the principle of plant addition is used to grow a green wall in the form of a tree network. This plant construct provides shading for the facades and local heat relief in the summer as well as influencing the wind flow of the street.		
Insect Hotels Insect hotels provide shelter and potentially a home for many species. Providing insect hotels for insects such as bees, hoverflies and beetles on the square could potentially increase the biodiversity there. Depending on the size and location of the insect hotels, they might also provide some shade and reduce heat on the square. In combination with signs explaining the purpose of insect hotels, an educational purpose can be added.		
Larger tree species Larger tree species may add multiple beneficial functions to an area where heat stress and a lack of biodiversity is in place. Larger trees provide plenty of shade, reducing temperatures in the surrounding areas. Large trees also provide shelter and habitat for animals. Plenty of bird species and insects are attracted to areas with larger trees.		
Modular wire-cube structures The cubic modules that make up this self-supporting structure are pre-cultivated to allow the vegetation to develop more rapidly. The result is a three-dimensional urban space that provides multiple vegetation-based ecosystem services: temperature regulation, air quality regulation, water regulation, noise reduction, habitat provision, aesthetic. This structure also provides important shade and sheltered areas.		
Outdoor furniture Benches built around tree trunks provide a place to rest in the shades. They add to the functionality of the square as well as the aesthetics.		

Permeable surfaces and tiles Additional permeable surfaces could be created on the square by replacing the current bricks with either solid and grass to retain water and reduce heat or with permeable bricks (e.g. with holes) so that green can grow along with the bricks.		
Rain garden A rain garden is a garden in a lower elevated area. The garden will be planted with grass, flowers and shrubs. Due to its lower elevation, rainwater is collected here, after which it infiltrates into the soil. Compared to regular gardens, rain gardens allow for 30% more water to soak into the ground. They also remove up to 90% of nutrients and chemicals, and up to 80% of sediments from the rainwater runoff. They need the same amount of maintenance as regular parks.		
Rainwater tanks Use one or multiple rainwater tanks to catch and store rainwater. This water could be used for irrigation of the greenery on the square. This rainwater tank and irrigation could be managed by either residents or the municipality. Costs can vary, but rainwater tanks can be installed relatively cheap.		
Raised Planting Bed with Vegetation Raised soil patches/beds could be added on the square to provide space for additional plants such as trees, flowers and bushes. This would reduce the heat stress, increase water retention and increase biodiversity. They also add to the aesthetics of the square if maintained well. With explanatory signs, they can also provide an educational purpose to readers.		
Trees in parking lot / Tree trenches The parking lot is a large area without shade, which increases the UHI effect of the square. Trees provide shade and conduct evapotranspiration, which both help with heat and decrease noise and wind. At the same time, trees provide space for biodiversity and can serve as wind-breakers. Planters for trees can also break up the monotonous flat parking area of the square to increase visual interest. Tree trenches are a way of planting trees along the parking spaces using less space than conventional tree planting areas. The trees are surrounded by permeable pavement letting water flow to the tree roots to supply them with water and lead excess stormwater to the subsoil.		

6.3 QUESTIONNAIRE

In addition to several informal interviews with the GTA as well as the café owner and artists working in the monumental building, a questionnaire was sent out to the café owner and the GTA. The questionnaire was mainly concerned with the ranking and prioritising of problems on the square that were experienced over the last few years. However, the questionnaire also had a section in which respondents could write about ideas for improvements or greening measures they had.

During the informal interviews that were conducted among residents, the café owner and artists, intermediate results could already be constructed. The aspects to be taken into account were narrowed down to a list that would be included in the questionnaire, to get a better idea of the priorities that needed to be focussed on first. Furthermore, during these informal interviews, we gathered that all the residents were aware of the GTA and that most of the residents are and want to be actively involved.

The questionnaire was filled in by seven people in total, who are all residents of the Transformatorplein. Six of these people were homeowners, and one person was a renter. Two people from the same house filled in the questionnaire, so these results were given half the weight of the others, to ensure that the results remained balanced in the sense that each house's input had the same influence on the results.

To fill in the questionnaire, residents could distribute 100 points among eight different aspects, according to which aspects they found the most important to be improved. Figure 22 shows the results of this question. From the pie-chart, one can see that biodiversity and habitat provision is a very important aspect that the respondents want to see improved (on average 24/100 points). The temperature regulation to improve the experienced heat stress by the respondents represents the second most important aspect that needs to be improved (18/100 points), closely followed by improvement of the water regulation (17/100 points). Aesthetics is also important to the respondents (12/100 points), followed by the wish for more privacy (10/100 points). Some of the less important issues included an improvement of acoustics on the square to reduce the noise nuisance (8/100 points) and a decrease of wind on the square (8/100). The least important aspect for the respondents is the functionality (i.e. recreation) of the square (3/100 points).

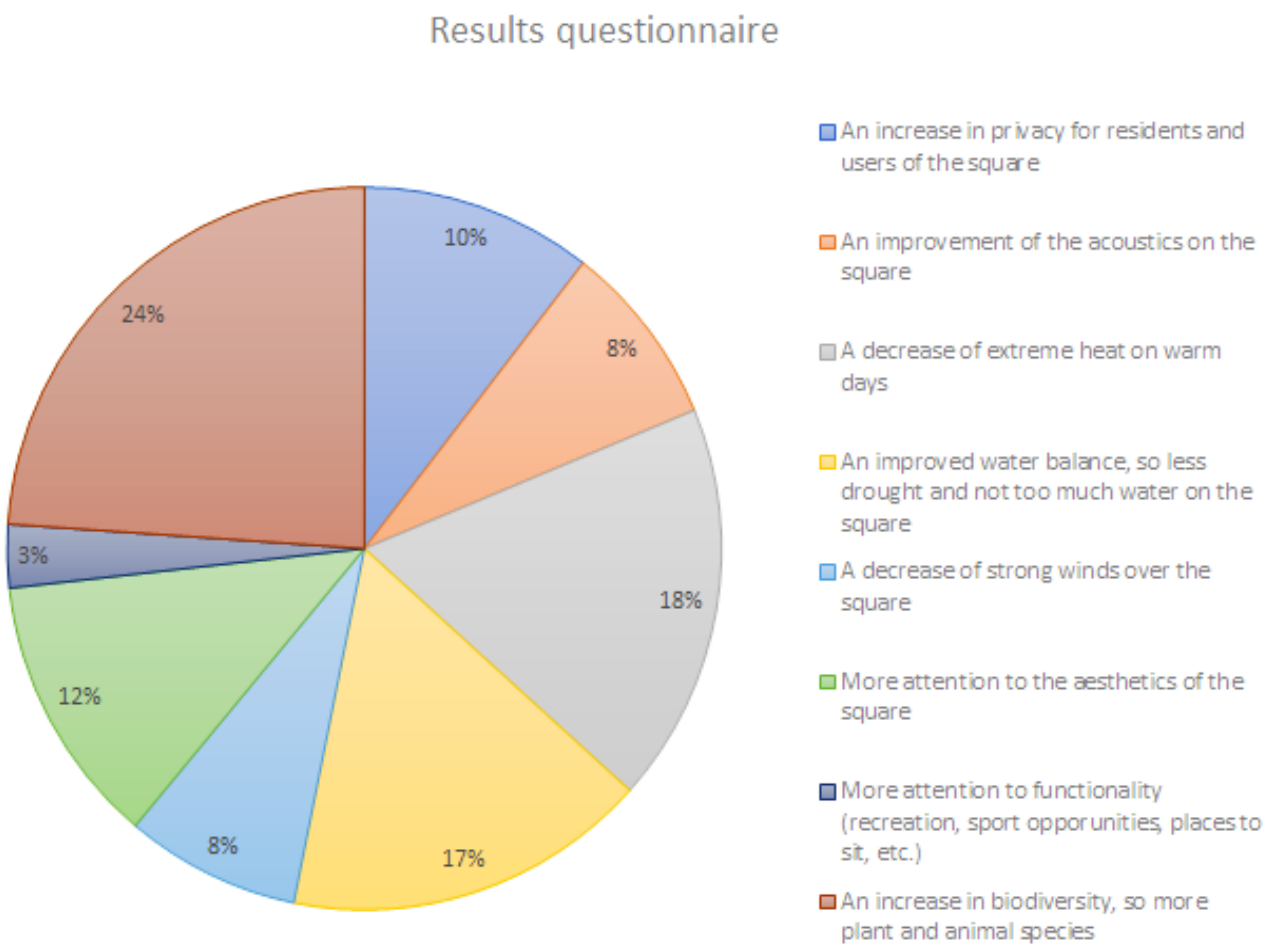


Figure 22 - Results from the questionnaire regarding the importance of different aspects ranking habitat provision (biodiversity), temperature regulation as well as water retention and regulation the highest.

Furthermore, a question was included regarding the willingness of the respondents to help with the maintenance and gardening of the square after the implementation of the measures. This question was included to become aware of how much of the maintenance would end up at the municipality, resulting in higher costs. The results of this question are presented in Figure 23. An interesting result is that none of the respondents is not interested in helping at all (0%). The largest group is willing to help, but only up to one time per year (72%). Furthermore, there are equal amounts of respondents willing to help between one and four times per year (14%), and more than four times per year (14%).

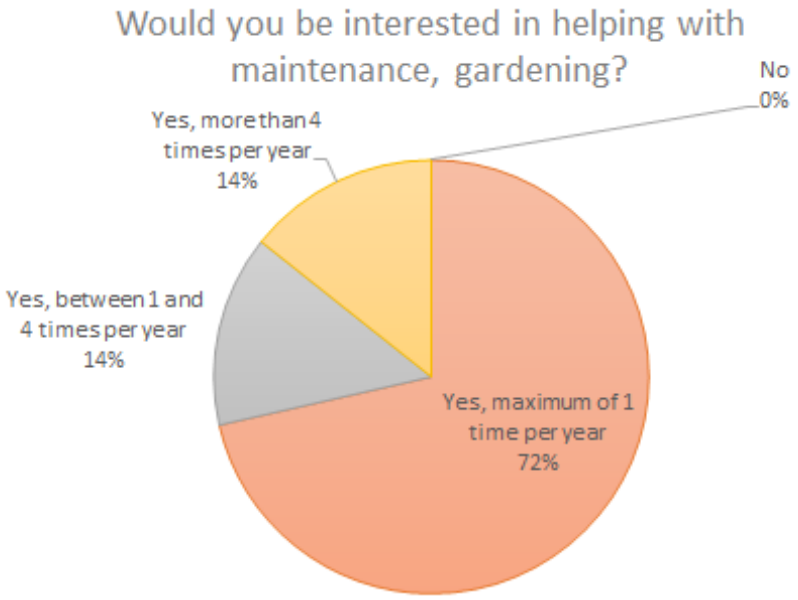


Figure 23 - Results from the questionnaire regarding willingness to help with maintenance showing that around ¾ of respondents are willing to participate.

Lastly, the respondents could name any additional comments they had. Only one person provided an answer. They wrote down 'many'.

6.4 Scenario Analysis

Four different scenarios were selected to zoom in on the development of the square in the years following the implementation of different combinations of the proposed measures. The scenarios have been chosen according to the results from the questionnaire, environmental issues regarding soil pollution and the ecosystem service analysis of the Transformatorplein. Each scenario incorporates different measures according to the ease of implementation and the ecosystem services provided.

The first scenario developed is the Paved Future scenario. This is a baseline scenario considering a future where no measures are implemented on the square and no further ecosystem services are provided. The analysis of this scenario is paramount to compare the effects measures will have on the Transformatorplein in the future.

The Quick Fix scenario was selected to study the impact of measures that do not need a removal of the paved area currently present. The presence of certain toxic elements in the groundwater and subsoil of the Transformatorplein has to be studied diligently before trees and other greening measures can be placed into the subsoil. This scenario circumvents the problems related to the pavement, water and soil by placing the measures on top of the pavement, for example by putting flowers in planters instead of in the soil. This scenario was chosen to represent the ecosystem services that can be provided on the square through measures that can be implemented easily, quickly and at a low price. Moreover, the outcome of the questionnaire sent to members (section 8.3) of the GTA provided insights on which ecosystem services to focus on. Because most participants considered an increase in biodiversity, an improved water balance and lower temperatures as the most important aspects that should change on the Transformatorplein, the focus for choosing measures in this scenario was based on those providing the previously mentioned ecosystem services.

The Green, Greener, Climate-Proof scenario explores the maximum provision of ecosystem services on the Transformatorplein while retaining most square functions. In the light of climate resilience, and how this is addressed in the city of Arnhem, this scenario was chosen to give an idea of what an ultimately climate-proof square could look like. This scenario requires invasive changes by stripping away large parts of the paved area as well as replacing the sandy layers with clean soil and will, therefore, be a costly solution. It was selected to represent the square with the largest possible provision of ecosystem services to adapt to climate change.

The Square of Possibilities scenario explores the provision of spaces for social interactions on the square while also focusing on ecosystem services, but not to the extent of the previous scenario. The functional use and its value to a neighbourhood are important design elements; therefore, the third scenario was implemented in the analysis. It was selected to exhibit a square that provides a more social and inclusive experience rather than strictly looking at possible solutions from an environmental perspective.

6.4.1 Scenario 1: Paved Future

In the Paved Future scenario, no greening measures are implemented on the Transformatorplein. The design and use of the square do not change from the example set in 2020. Apart from the already existing raised vegetated areas in Zone 2 and on the northern parts, the square remains paved (Figure 24).

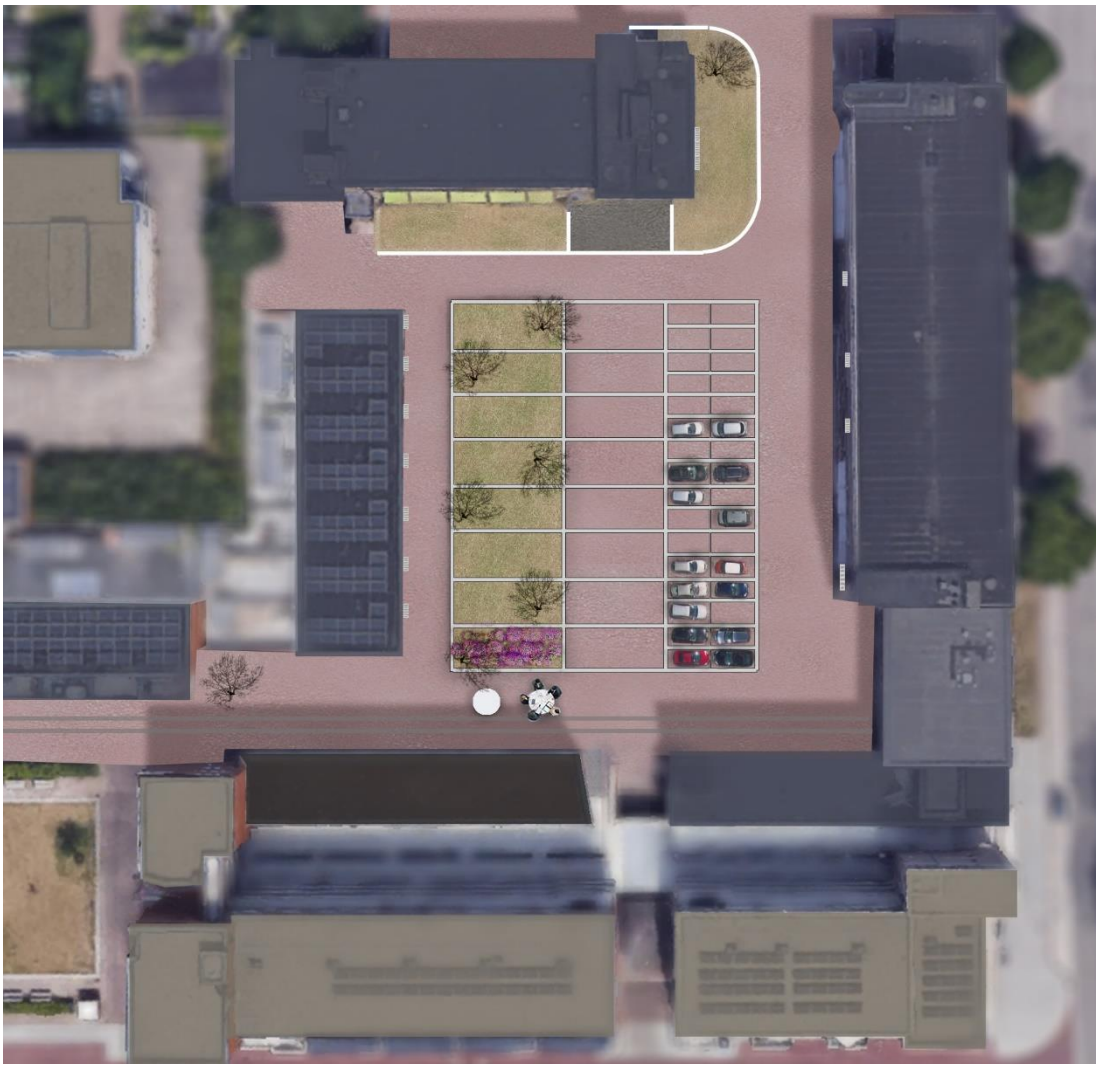


Figure 24 - The Paved Future scenario consists of dry and plain spaces.

During heat waves, the lack of shading or evapotranspiration on a large part of the square will negatively impact the thermal comfort of its users. The pavement will heat up considerably during summer periods and the area will be unpleasant for both humans and animals during the hotter summer months. Additionally, droughts will further continue to damage the existing green spaces, transforming them into dry, dead zones in the summer months. The walnut trees develop poorly and might eventually die off entirely due to the lack of water in the raised vegetated zone. In autumn and winter months, the prevailing winds on the square make the square cold and unpleasant for human enjoyment for prolonged periods of time. Heavy rainfall events will discharge over the square surface to the puts along the sides of the square and bordering Zone 2. This water will be discharged through the sewer system, potentially causing pollution near combined sewer overflows during particularly heavy storms. This water cannot infiltrate to groundwater to prevent droughts in the subsurface. When the sewer system is unable to handle the excess, water will pond on the Transformatorplein itself. Biodiversity is low on the square. Apart from residents planting some new, visually interesting flowers the raised area in the centre of the square has limited vegetation: walnut trees and grass. Animal presence is limited to the vegetated area in Zone 2, small numbers of animals frequent the square. Apart from the vegetated eastern area, the square is visually unattractive and not a place suited for human enjoyment. Around the café and in front of the residential housing, people try to make their spaces on the square more enjoyable. Nevertheless, the front yards of houses are not preferable over the privacy and calmness experienced in their backyards.

The Paved Scenarios Analysis makes it clear that the Transformatorplein will remain an unattractive square if business continues as usual. It would not contribute to a climate-resilient Arnhem. Moreover, in the light of climate change, the negative aspects, such as the heat and drought, may even increase.

6.4.2 Scenario 2: Quick Fix

Implemented measures

In the Quick Fix scenario, the implemented measures specifically focussed on decreasing heat stress, which improves water retention and increases biodiversity, making the square more climate-proof. This scenario has the least associated costs because there is no need for remediation of the soil. In this scenario, all the currently paved surfaces on the square remain paved and the measures are simply placed on top of the surface to cover the pavement with green spaces (Figure 25).

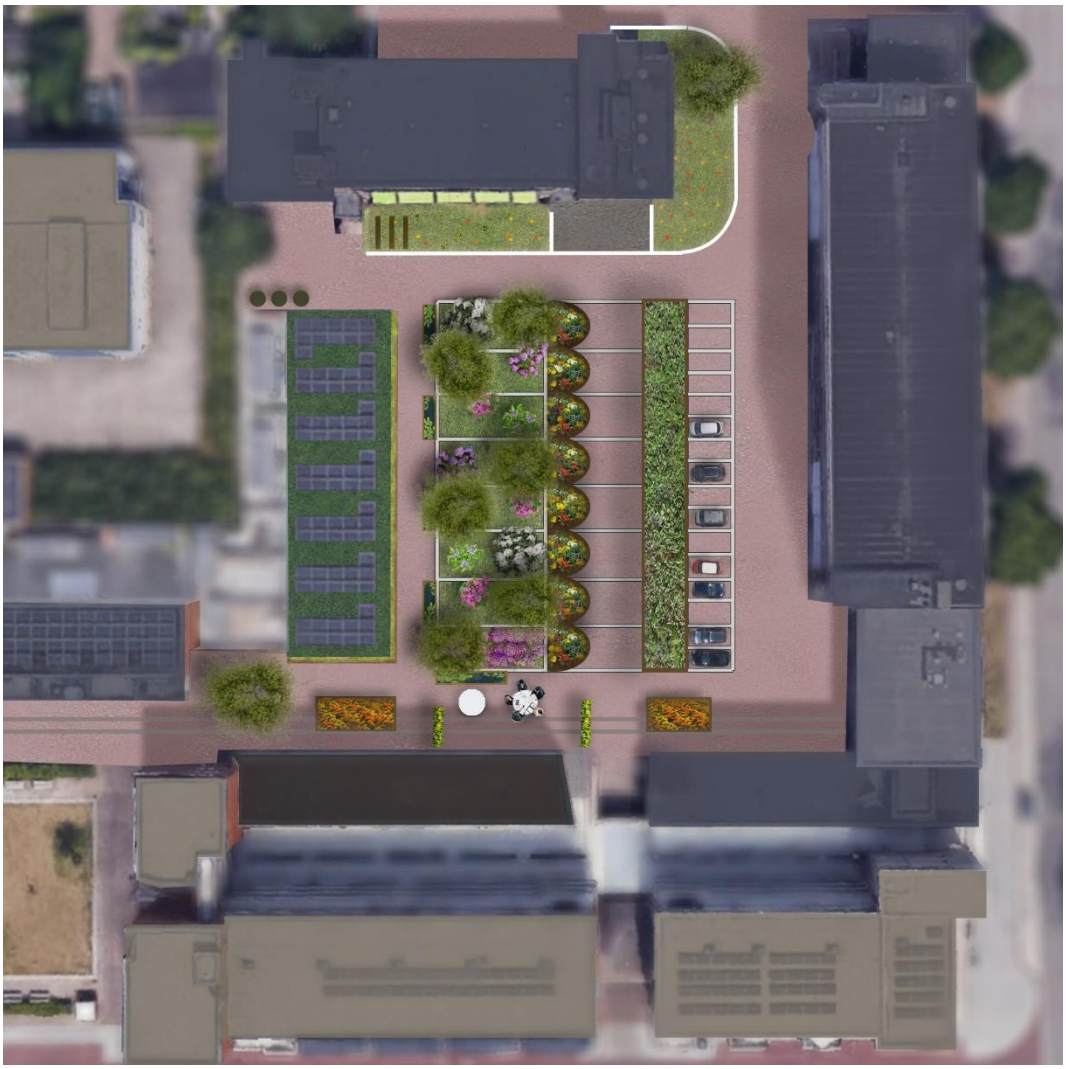


Figure 25 - The Quick Fix scenario contains many raised beds with flowers.

In regards to the measures for this scenario, rainwater tanks will be placed next to house number 27. This location is most suitable because it offers plenty of shade, is out of sight and has the least negative effect on the aesthetics of the square. Three tanks will be placed in total and are used to store rainwater run-off from the roofs that can be utilised to irrigate the greenery on the square, especially in the summer when water is scarce. This adapted watering strategy could also relieve the water stress of the city in the summer because the Transformatorplein can sustain itself during critically dry weeks. Installation, maintenance and costs of these tanks are not very high, and thus, this is an effective measure for this scenario. Furthermore, free-standing mini-ponds will be placed in front of some of the houses, to create more biodiversity as well as having a small cooling effect on the nearby area. A small number

of these mini-ponds will be placed in the space between the houses and the raised vegetated area. Such ponds could be adopted by the residents who would take care of them and maintain them. Moreover, birdhouses will be placed either in the private back yards of the houses, on trees on the square or under the roofs of houses to increase biodiversity. Next, a construction botany in form of a green wall will be applied to the facades of the houses to create green walls, which will have multiple positive effects. They will simultaneously increase biodiversity, decrease heat stress, and dampen sound. Lastly, green roofs are an option for residential houses on the square. These have a cooling effect but could be tricky to install due to the presence of solar panels on the rooftops.

In Zone 2, the raised vegetated area will remain. Small bushes and plants will be planted, which will have a positive influence on biodiversity, as well as dampening sound and wind, decreasing heat stress, and increasing water retention. Specific flowers will also be planted, which can handle the juglone that is produced by the walnut trees (section 10). These flowers will not only enhance biodiversity but also the aesthetics of the square.

Lastly, in Zone 3, multiple greening measures will be applied as well. To begin with, a green parking lot roof will be constructed. This will allow the parking spaces to retain their function while offering options for more biodiversity on the roof as well as a large cooling effect on the square and offering shade for the cars. Such a roof would only be placed on the row of parking spots closer to the centre of the square to distribute shade optimally following the direction of the sunlight but will not create too much shade on the square to make it unpleasant. Secondly, raised beds with flowers will be constructed adjacent to the raised vegetated areas, to offer heat relief, water retention, biodiversity, and improve the aesthetics. Furthermore, a free-standing mini-pond is proposed next to the café, as well as two movable free-standing green walls. The movable green walls will offer privacy and will reduce the noise coming from the café's terrace. They will also provide biodiversity and heat relief and are visually attractive for the residents and the visitors of the café. Additionally, near the monumental building at the north of the square, spring flowers such as daffodils and tulips will be integrated into the grass, insect hotels will be placed and wildflowers will be added. Lastly, two raised beds with flowers will be placed on the square, one in the southeastern corner of the square and one in the southwestern corner of the square. These will enhance biodiversity as well as offering water retention and improving aesthetics.

Expected scenario in 2025

In the year 2025, half a decade has passed since the measures of this scenario were implemented. Additions to the square like the bushes in Zone 2 and the plants on the walls have had time to mature (although to a lesser extent than trees would have matured visually).

The additional vegetation now growing on the green roofs of the buildings and the carports, has a small effect on the heat experienced on the square. But, the parking lot roofs provide some much-needed shading for parts of the paved square as well as half of the cars. The area is still warming up during hot summers. In a heatwave, the square is not the most pleasant place to be but the issue has not gotten worse. The addition of rainwater tanks storing excess water from the roofs reduces some water stress from the sewage systems of the area as well as provide additional water for irrigation. The rainwater is used for the watering of plants on the green walls as well as in Zone 2. Drought effects are therefore partly mediated in the vegetated areas and the plants there have started looking healthier.

The now established flower beds attract more wildlife to the square. The flowers are regularly maintained to keep them growing beautifully and healthy. The positive effects of the flower beds can

particularly be enjoyed in the blooming season. Especially the raised beds in the centre of the square are very colourful and attract an array of wild pollinators. Some small birds frequent the bushes in Zone 2. Larger birds frequently visit the square to search for leftover food and walnuts, however for nesting, they will move elsewhere as the trees on the square are not large enough for most large bird species. The extreme winds in some parts of the square are now a little less extreme thanks to the additional bushes that have been planted in strategic locations all over the square. Along the southern edge of the square winds can still dominate and on cold days this experience is uncomfortable.

Noise at the resident housing is mitigated by the blocking of the front gardens through bushes and softer plant materials on the facades as well as the green walls at the café. Front gardens on the western side of the square are generally more pleasant with more greenery and privacy instead of a direct view on the car park in front and the café on the side. The general aesthetics of the square have improved in comparison to the paved area it was before but especially during autumn and winter the square still resembles a partially bleak landscape. Overall, there are still little opportunities to socialise and enjoy the positive aspects of climate. There are not many thoroughly shaded areas to sit and enjoy lunch or meet the neighbours outside of the cafe. But there is also a significant increase in urban green spaces. More vegetation is now installed influencing the atmosphere on the square positively.

Concluding, the Quick Fix scenario describes how the Transformatorplein can change without too many invasive interventions such as soil remediation. Therefore, the costs will be low and the ecosystem services will be delivered in a relatively short time span. The greening measures do not necessarily contribute to a square for the whole neighbourhood but are mainly set-up according to the wishes of residents.

6.4.3 Scenario 3: Green, Greener, Climate-Proof

Implemented measures

The Green, Greener, Climate-Proof scenario focuses on the complete greening of the square. This scenario takes financial restrictions into a lesser account, allowing for a great variety of measures to be implemented. The first 1.5 metres of soil will be completely remediated and replaced with clean soil as well as sealed off from the ground below to prevent any intervention from soil and groundwater pollution on measures on the Transformatorplein. Current functional uses of the square are expanded and moved to create an optimal situation for the greening of the square (Figure 26).

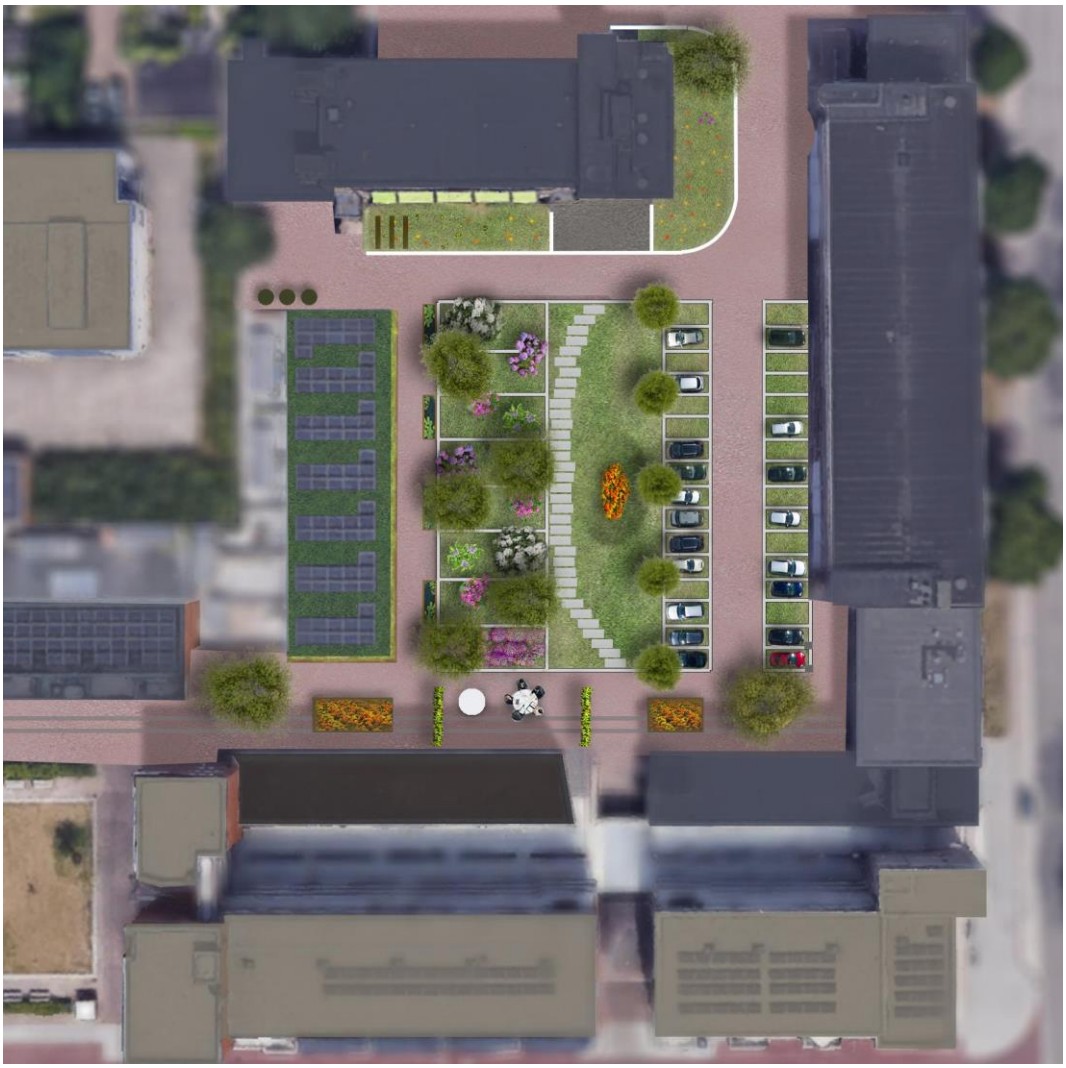


Figure 26 - The Green, Greener, Climate-Proof scenario includes many large green spaces.

In Zone 1, measures will be implemented to decrease heating on the square. Besides the current gardens in front of the houses, multiple walls will be greened with a wide array of plants. These green walls will catch solar radiation and prevent the bricks of the houses from overheating. Additionally, evapotranspiration will help cool the square during warmer periods. Furthermore, the green walls may also decrease the echoing effect of sounds on the square as green spaces are able to soften noises to various degrees.

In Zone 2, the remediated soil gives more room for the roots of trees to grow downwards, thus allowing for bigger trees to grow. These trees will provide more shade and evapotranspiration causing a significant cooling effect on the square, while simultaneously serving as windbreakers and screens for increased privacy. The larger trees also provide a suitable habitat for insects and birds, increasing the biodiversity on the square.

In addition to the trees, bushes and flowers will be planted in Zone 2. Bushes may provide several services such as providing shelter, food in the form of berries and insects attracted, cooling through the shade, and transpiration. The bushes may also reduce noise pollution and help improve privacy by functioning as a barrier. The flowers provide nutrient sources for insects such as bees and help with water retention.

Due to the remediation of the soil, plants can now be directly planted into the exposed soil in Zone 3. This area can be used to create a rain garden. The lower ground level of the rain garden will allow rainwater to be retained in the zone, providing the surrounding areas with plenty of water. In addition to the benefits of its water retention, a rain garden will also have a cooling effect as well as further reduce the echoing effect of noise on the square. Rain gardens also provide their own unique vegetation, attracting different animals to the vegetation in Zone 2.

The parking area will be relocated to create more room in Zone 3. The parking row on the side of the big monumental building will be moved to the immediate front of the building. This restructuring creates an area in between the parking rows for cars to use to enter and exit the parking space resulting in more efficient use of space as cars can use one road in the middle of the parking lot to park instead of using both sides of the parking area. Therefore, Zone 3 can be extended all the way to the first row of parking spots, almost doubling the initial size of the zone. Additionally, trees will be placed at the outer side of the centre row of parking places to provide shade for the cars, as they experience significant heat during the summer months if they stand in direct sunlight (Figure 26). Additionally, the trees will also provide further cooling through evapotranspiration.

The pavement of the parking spaces itself will be changed to permeable bricks that allow for vegetation to grow in the gaps. This allows for more water retention in the parking space area, reduces the heating effect of the square through the creation of a greener surface, and significantly reduces the echoing noises on the square.

In the area around the café, movable free-standing green walls will be placed which can be used for different types of vegetation. These walls alone will reduce the noise pollution of the café and reduce wind disturbance for the café itself. Placing flowers on the green wall creates a habitat for insects and increases biodiversity for the square slightly.

Other small measures which will be incorporated in this scenario are the addition of birdhouses to improve the square for these types of animals and rainwater tanks which will be placed alongside the residential houses to catch an excess of rainwater in periods with higher precipitation to be used in times when precipitation is low. Lastly, the area around the monumental building containing the architect agency could be improved with more diverse vegetation. Adding trees, bushes, spring flowers, wildflowers and insect hotels would provide more possibilities for shading and transpiration on the square in this area as well as an increase in biodiversity. Finally, other measures from previous scenarios will also be implemented such as green roofs for residential houses and mini-ponds. Lastly, two large

trees are added on the south-west and south-east side of the square close to the café and a monumental building.

Expected scenario in 2025

After five years, the vegetation on the square has had time to mature and grow. The vegetation can provide ecosystem services even under more extreme climate anomalies. The green walls on the houses, green rooftops, green parking spaces, the rain garden, the trees in Zone 2 and in the parking lot and the bushes all add to the vegetation of the square. All these plants obstruct sunlight from heating up the square. Heatwaves have a much lesser effect and the Transformatorplein has a pleasant atmosphere even during the increasingly hot summers.

The infiltration of rainwater on the square in the flower/grass bed in Zones 2 and Zone 3 and the tree rooting zones decreases pressure on the sewage infrastructure during heavy rainfall events. If the infiltration proves to be high enough, the square can be decoupled from the sewage system. The enhanced infiltration can also help mitigate drought periods in the vegetation, which in turn allows more evaporation during these periods with high temperature. The green area in the urban landscape has increasingly gained the attention of animals throughout the years. Insects are attracted to the blooming flowers and bushes, attracting birds in turn. The sight of different kinds of birds flying through the square is commonplace. Residents enjoy sitting in their front gardens again to look at them.

The trees, even though still young, and bushes help in dampening the effects of prevailing winds and provide a sheltered and private feeling. In early spring, the square is a nice place to catch the first sunshine of the year and in colder months the heavy winds have less effect on the square, ensuring it is more pleasant during these months. Residents and their homes are not visible to the entire square anymore and the vegetation filters the noise of traffic and people using the square. On the new square, sensory experiences for people are reduced. Heat, water and wind issues are experienced much less and the Transformatorplein becomes a welcoming place for people to relax instead of a simple paved area with little visual interest.

The Green, Greener, Climate-Proof scenario is high in costs, but the soil underneath the Transformatorplein will finally be completely remediated. Even though it will take time for some of the measures to be implemented and the vegetation to be fully grown, the Transformatorplein of this scenario is truly climate-resilient.

6.4.4 Scenario 4: Square of Possibilities

Implemented measures

In the Square of Possibilities scenario, the current function of the square changes little in terms of location and surfaces. The pavement is removed in parts of the parking zone as well as in the southeastern corner of the square. New clean soil is placed instead of the sand to give space for trees there. The car park is slightly adapted because some parking spots now come with a charging station for electric vehicles (Figure 27).

Figure 27 - The Square of Possibilities Scenario contains a green living room made from modular wire-cubes.

On and around houses measures like mini ponds and birdhouses provide biodiversity interesting to look at for residents and visitors of the square. Looking at birds drinking at ponds or feeding their chicks in birdhouses is a new experience in the urban landscape. Visitors, young and old, are free to use some of the buckets available and use the taps on rainwater tanks next to number 27 to water the plants. Throughout the square, flowers with different blooming seasons are added in many areas where previously only pavement or grass was present. The overall aesthetics of the square are improved, immediately visible when visiting the square from all entrances.

Zone 2 is restructured with more biodiversity in mind. Bushes and flowerbeds, along with the existing walnut trees enhance the aesthetics of the resident housing on the east side of the square and the café while providing a visual blockade to the rest of the square and enhancing privacy. On the south end of the raised area, a wire-mesh structure is implemented to further increase shading and help diffuse noise.

In Zone 3, vegetation is placed. Because the soil is not remediated, modular wire cubes with integrated soil pockets are placed in the zone, building several walls on which plants and flowers can grow as well as providing additional seating. The wire cubes are constructed in such a way that the seating areas face each other instead of the parking lot or the residential housing to provide an optimal experience for visitors as well as residents. The seating will invite people to take a pause from their busy urban lives and appreciate the nature around them. Additionally, the green walls that are constructed with the wire cubes provide a dampening effect for noises, a shaded area and a cooling effect through the evapotranspiration of the plants.

Around the square, infographics about the project and the present habitats could be added – for example on the biodiversity effects of wire-mesh green structures, flowerbeds and less strictly mowed perennial grasses. In the car park, space is made available for green wall mesh structures with integrated soil where climbing plants can grow on. These structures will provide cooling through providing shade and evapotranspiration, but to a lesser extent than trees can. Lastly, a large tree with a round bench around it will be placed in the otherwise plain south-eastern corner of the square. This means that the pavement in that area has to be removed and replaced with clean soil. On the round bench, residents, artists, architects and other people from around the square can take a lunch break or enjoy the sunshine for a while.

Expected scenario in 2025

After five years have passed, heat waves during summers will have a lesser effect on the square. By reducing the amount of visible pavement and creating shaded areas through vegetation constructions, the heat absorbed by stone surfaces is reduced and evapotranspiration is possible when water is available. The heat experienced on the square will also be mitigated slightly by the tall wire constructions in the parking lot. The constructions are reducing the amount of sunlight reaching the stone surface and the green vegetation attached to them provide evapotranspiration in all but the most extreme drought periods. Natural infiltration is increased because the wire constructions in the parking lot and in Zone 3 soak up significant amounts of rainwater. This increased infiltration is however not enough to stop the reliance on the sewage system under the square. Extremely heavy rainfall events can still potentially lead to flooding of the puts.

The addition of plant species in all three problem zones of the square enhances biodiversity on the square. With the addition of bushes, flowers and perennial grasses in Zone 2 and three as well as the addition of spring flowers and wildflowers on the other grass strips, insects can be attracted to these areas. By adding infographics to the constructions, people on the square can understand the transformation and its provided value better and appreciate this new life in the city. These insects will in turn attract bird species, which are also more drawn to the area due to the increased tree cover. The addition of bushes, a large tree and wire mesh vegetation throughout the square will help with the experience of wind on the square. The winds are partly broken and reduced by the higher vegetation instead of blowing straight across the square and a dampening effect on noise takes place. The vegetation in Zone 2 and Zone 3 additionally divides the residential areas from the café and the square so that privacy is provided for the residents.

The Square of Possibilities is both inclusive for the whole neighbourhood as well as providing some ecosystem services through greening. This scenario reflects a square meant for the whole neighbourhood to enjoy. Only parts of the soil will be remediated and therefore, the implementation is not extremely invasive nor expensive.

7 Discussion

In this report, an extensive research into the greening options for the Transformatorplein in Arnhem was conducted. In the following sections, the results for each sub-question are interpreted and discussed. A critical view regarding the limitations of the research is also included.

7.1 Current situation on the Transformatorplein

What is the current situation on the Transformatorplein regarding environmental issues?

Firstly, the current problems on the square have been identified. It was established that the current design of the square influences the temperature and noise levels, water retention and wind intensity. Secondly, the soil, as well as the groundwater on the site, are polluted from previous industrial activities on the site. Thirdly, due to the current abundance of paved surfaces on the square, a lot of heat gets trapped there in the summer, which is additionally worsened by the UHI effect of the city. Those surfaces also influence the way sound travels on the square, providing lots of room for echoes. Furthermore, they pose stress onto the water absorbance of the square in extreme rainfall events but do not retain water for drought events. The currently existing architecture on and around the square creates wind channels especially in the southern part of the square.

Currently, the wind can form strong wind channels on the square because of the walls of the buildings and the limited number of wind-breakers present on the square such as trees, bushes, walls, installations, benches and other uneven and irregular surfaces. Noise is echoing across the square due to tall buildings and the paved surfaces.

The contamination of the soil to a lesser extent and contamination of the groundwater to a much stronger extent are still present and especially the soil would have to be remediated to be able to plant trees and other plants on the square. Currently, greening measures have to be installed on top of the paved brick surfaces. Because the current soil layers under the brick pavement cannot be easily replaced with clean soil, such remediation is associated with high financial expenses. Moreover, there is some unclarity regarding the soil pollution and soil layers underneath the different zones of the square which needs investigation before remediation starts.

The juglone from the walnut trees makes it difficult for plants to grow under the trees. This can make the green stripe appear bleak. Therefore, specific plants should be placed there.

The overall ability of the square for water retention is significantly reduced due to the paved areas. Water is likely to flow through the sand layers and to end up in the groundwater and the Rhine, or it flows through the sewage system as runoff. Therefore, it currently provides little value to the square and could be used more efficiently to water current green spaces as well as potential future ones.

7.2 PROVISION OF ECOSYSTEM SERVICES AND GREENING MEASURES

Which greening measures can be taken to improve the ecosystem services on the square?

A multitude of measures is available to mitigate problems associated with the urban climate. Many of these measures are associated with increasing the amount of vegetation and biodiversity on the square. The positive aspects associated with increasing the number of green spaces in general help across multiple ecosystem services. The complete list of measures considered in the context of this study is available in section 8.2.2, and Appendix 13.3 contains a more detailed description.

What is the potential of ecosystem services to positively affect the square?

There is a great potential to improve the ecosystem services provided by the square. Currently, the square does not provide many ecosystem services at all. The design of the square seems to have been focused on providing a large paved area, which is not a conducive environment for the provision of services.

The Transformatorplein has multiple areas in which an environment where heat, wind and noise become less of a problem for people could be created. There currently is little shelter provided by vegetation or structures and with less than optimal climate, being on the square is not a pleasant experience. From a perspective of climate-proofing the square, there is minimal water retention by vegetation and soil as well, adding surface runoff to the sewer system during heavy rainfall.

While not strictly an ecosystem service, the overall atmosphere of the square can be improved by a lot as well to provide an area where the positives of urban life can be celebrated.

What are promising greening measures that can be used to enhance the provision of ecosystem services on the square?

In the second part of the report, measures to improve the provision of ecosystem services have been identified. The landscape analysis of the first part was used to filter a wide array of greening measures and to select the ones that could be implemented on the Transformatorplein under the current circumstances. The chosen measures influence more than one ecosystem service positively at a time. The suggested measures rank from cheap and easy to implement to expensive and extensive in implementation. An overview of possible measures was provided in section 8.2.2 as well as a detailed description of each of the measures in Appendix 13.3.

7.3 PRIORITIES OF GTA AND CAFÉ OWNER

What are the priorities of the GTA and the café owner regarding the ecosystem services of the Transformatorplein?

The input of the residents and the café owner was gathered by sending out a questionnaire to them. The results from this questionnaire were used to narrow down the most important aspects that needed to be improved on the square and set up the scenarios. The café owner did not fill in the questionnaire, seven residents of the Transformatorplein did fill in the questionnaire, two of which from the same house. In order to distribute the weights from each house evenly, the input of the two people from the same house was given half the weight of the other inputs.

From the results of the questionnaire, it became clear that increasing the biodiversity, decreasing the heat stress, and improving the water balance are most important to the respondents in the

questionnaire. Therefore, these three aspects were incorporated most in the scenario analysis, especially in the Quick Fix scenario, which is the cheapest to realise in terms of cost and construction.

In the questionnaire, the last question was 'Do you have any additional comments?', after which the questionnaire ended. People could fill additional comments, but there was no way of getting back to them for clarification if necessary. To get a better understanding of the respondent's perspective, contact details should be left behind.

7.4 FUTURE SCENARIOS AND THEIR IMPLICATIONS

How could the implementation of different combinations of measures affect ecosystem services provision on the square in the coming five years?

In sections 8.4.1 - 8.4.4, scenarios on the development of ecosystem services in the next five year following implementation of different sets of measures are discussed. Detailed descriptions are available in this section.

Depending on how extensive the measures used on the square are, the ecosystem services can be greatly affected in the future. The sets of measures that can be implemented are partly dependent on stripping out pavement and remediating the subsoil to ensure vegetation can root deeply and water can infiltrate instead of being led throughputs. Large vegetation can help especially with the climate-proofing of the urban landscape, but this does require soil remediation. This is an expensive prerequisite for some of the measures and the budget will have to be considered before implementation. Measures on top of the paved surface can still help with ecosystem service provision while having a lower cost.

Which scenarios can be chosen based on the current situation, the identified measures and the needs of the GTA and the café owner?

Four scenarios were chosen: i) Paved Future, ii) Quick Fix, iii) Green, Greener, Climate-Proof, and iv) Square of Possibilities. One of the defining factors for choosing the different scenarios was the fact that the soil needs to be remediated in order to remove much of the paved area and plant vegetation. Remediation is expensive and therefore it is only included in one of the scenarios. Another defining factor for deciding on the different scenarios was the current situation of the square. The parking spaces need to retain their function and the market should still be able to take place here. Therefore, we made sure that all scenarios kept the same amount of parking places and open space. Lastly, the needs of the residents were taken into account to decide on the scenarios. Only the most important needs were focussed on in the Quick Fix scenario, to keep it relatively cheap and easy to implement. The other needs were implemented more in the Square of Possibilities, also taking into account the possible needs of other people, such as the café owner or the artists. The Green, Greener, Climate-Proof scenario takes all the needs of the stakeholders into account.

Which measures will be considered on the square for each of the scenarios?

For the Quick Fix scenario, no measures are considered. This is the baseline scenario, which is used to evaluate the other scenarios.

There are multiple measures that will be applied for all other three scenarios: rainwater tanks, free-standing mini-ponds, green roofs to the residential houses, spring flowers, wildflowers, insect hotels, bird boxes, and movable free-standing green walls.

Specifically for the Quick Fix scenario, green walls will be applied to the residential houses. In the raised vegetated area, small bushes and plants will be planted, as well as specific flowers able to tolerate the

juglone produced by the walnut trees. Lastly, a green parking lot roof will be constructed, and raised beds with flowers will be constructed adjacent to the raised vegetated areas.

For the Green, Greener, Climate-Proof scenario in specific, construction botany will also be applied to the residential houses. Due to the remediation of the soil, larger trees can grow in Zone 2, as well as bushes and flowers. A rain garden will be constructed in Zone 3, also due to the soil remediation. The parking lot will be relocated slightly, and trees will be planted as well. The surface of the parking lot will change from paved to grass. Lastly, two large trees will be added on the south-east and the south-west side of the square.

Specifically for the Square of Possibilities scenario, flowers with different blooming seasons will be added throughout the square. Regarding the raised vegetated area, bushes and flowerbeds will be added, as well as a modular wire cube structure at the southern side, at the café terrace. More of these modular wire cube structures will be realised in Zone 3. In the parking lot, a green wall mesh structure will be constructed. Furthermore, a large tree with a round bench around it will be placed in the south-eastern corner of the square. And lastly, infographics about the project are placed around the square.

How will different scenarios play out over a course of five years?

Lastly, a scenario analysis was conducted to play with a combination of measures and the influences their implementation may have on the square. The Paved Future scenario plays with the continuation of the existing conditions on the Transformatorplein. If no greening measures are implemented, the current problems on the square will intensify. The Quick-Fix scenario imagines changes to the square that are easy and cheap to implement. This scenario sees a positive influence on increasing biodiversity, decreasing heat stress, and improving water retention to generate a more climate-proof square. The Green, Greener, Climate-Proof scenario imagines the implementation of the maximum amount of greening measures on the Transformatorplein. Here, the ecosystem services that will be positively influenced the most are temperature regulation, water retention and regulation as well as wind regulation.

7.5 Limitations of the Research

The report on greening the Transformatorplein is based on different analyses of the square. One area where the methodology could be improved is with the inclusion of a stakeholder analysis. The report has included a questionnaire mainly answered by residents. For a more complete view on the implementation and impact of measures in the area, other stakeholders like the municipality and non-residing users of the square as well as business owners should be included. Due to constraints in time and resources, this was not conducted during this project. With a greater research period further greening measures could be evaluated for implementation.

Moreover, the soil was not evaluated regarding the quality, content and moisture levels, but this would have made it more clear what the exact growing conditions are, and which areas need remediation before specific measures can be implemented. The situation regarding precipitation runoff on the square was not looked into for this project. Looking into these processes would have given an indication of the amount of water precipitates onto the square per year, and could have helped with deciding on measures. This was not included in this project due to constraints in time.

8 Recommendations and Conclusion

In this section, the project team concludes with recommendations on the possible improvements of the Transformatorplein. These recommendations stem from an academic background in urban management and the experience with the square and the problems associated with it during the project.

- **Increase the potential of the Transformatorplein.**

The Transformatorplein is a historic place in Arnhem. The square has a large potential as a place where people can enjoy its history and the urban landscape. Transforming the Transformatorplein to a climate-resilient green urban area, taking both ecosystem services as well as the (aesthetic) value for the neighbourhood into consideration, will add another chapter to this varied history.

- **Increase the amount of green space on the Transformatorplein.**

Looking at the Transformatorplein from an ecosystem service perspective it is apparent that the square does not offer any pleasant areas to users outside from parking and visiting the cafe. The climatic problems associated with an urban landscape are also only likely to get worse in the future, further decreasing positive experiences at the square. For this reason, a main recommendation of the team is to increase the green space at the square if at all possible. Any increase in ecosystem services on the Transformatorplein will be a worthwhile investment in the health and happiness of citizens in the area.

- **Conduct an extensive stakeholder analysis before choosing measures to implement on the square.**

A comprehensive stakeholder analysis is not conducted in this project. Before the implementation of measures on the square, a comprehensive stakeholder analysis is recommended, taking into account future uses of the square by for example the municipality. Appendix 12.2 offers more detail on stakeholder analysis.

- **Analyse the square in more depth before deciding on measures to implement.**

Thorough research and data analysis should be done on the situation on the square before the feasibility of implementation can be certain. Looking further into depth in soil quality and type, precipitation and drought on the square will give an indication of the actual growing conditions on the site. The feasibility of measures can then be researched accordingly. The preferred option of greening as seen by the team would be larger vegetation like trees. This would require expensive remediation of the soil but will greatly enhance square functions like infiltration of water to mitigate drought. The larger vegetation can greatly help with heat stress, increasing biodiversity, wind and noise problems. The general atmosphere of the square would also benefit from increased tree cover. Remediating the soil offers opportunities to improve not only the square, but the whole area, and increase its climate resilience. Consequently, the Transformatorplein will contribute to a higher extent to a climate-proof Arnhem. Besides conducting an in-depth analysis of the environment, the current vegetation should also be assessed and used for planning. For example, the walnut trees will limit the growth of other plant species. In this area, one should select for plants that can deal well with potential soil pollution from Juglone and low light conditions. These include species such as (1) the European wood anemone, daffodils, tulips and crocuses, which are all not affected by juglone because they bloom in spring, (2) the Bergenia, which is not native but can deal well with salty soil and shade, (3) the Asian Hosta which can be cultivated in pots

and thrive in low-light conditions, and (4) bushes such as Hydrangeas and Rhododendron, which can be planted near but not under the trees (Gartendialog, n.d.).

- **Looking at the different soil layers for the whole area before remediation.**

Before remediation of the soil starts a thorough investigation of the pollution, as well as different soil layers, is highly recommended. With remediated soil, an area on the square level could be devoted to other vegetation as well, providing a nicer area for human experience while increasing climate-proofing of the area.

9 Recommended Literature and Further References

The following literature related to greening measures and climate in the city is recommended for further reading:

- Information on the climate in the city
    - Lenzholer, S. (2015). *Weather in the city*. Rotterdam, the Netherlands: Netherlands Architecture Institute.
- Information on different greening measures and how to install them
    - A booklet written in Dutch by van Veen, A., Pötz, H., Dirckx, L., van Beurden, C., Horstra, B. & Huisman, M. (2018). *Handboek voor de Watervriendelijke Tuin* [PDF], can be retrieved from https://www.tuinbranche.nl/Uploaded_files/Zelf/totale-handboek-incl-infobladen-lichte-versie.e1233f.pdf
- Information on flower meadows
    - The book Ketelaar, H. (2018). *Planten van hier*. Zeist, the Netherlands: KNNV Uitgeverij.
- Information on the construction of insect hotels
    - van Breugel, P. (2017). *Gasten van bijenhotels*. Leiden, the Netherlands: EIS Kenniscentrum Insecten & Naturalis Biodiversity Center.

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APPENDICES

A.1 QUESTIONNAIRE

The questionnaire that was sent is shown below; on Friday the 2nd of October 2020 one of the commissioners sent the questionnaire to all members of the GTA and the café owner. On Wednesday the 7th of October 2020 the answers were analysed. All participants were anonymous and the opinions of people residing in the same house were given a lower weight to ensure that all the houses had the same influence on the output.

Vragenlijst vergroening Transformatorplein

Beste bewoner/gebruiker van het Transformatorplein,

De bewoners van Transformatorplein nummers 15 tot 27 hebben een bewonersinitiatief gestart om het plein groener en aantrekkelijker te maken. Om advies in te winnen hebben zij onze hulp ingeschakeld. Wij zijn een interdisciplinair team master studenten van de Wageningen University & Research en fungeren als consultants voor het bewonersinitiatief.
Er zal door ons gekeken worden welke ingrepen in de openbare ruimte mogelijk zijn om het plein te verbeteren en aantrekkelijker te maken ten aanzien van de thema's biodiversiteit, de waterbalans, temperatuur, wind, akoestiek, privacy, functionaliteit en esthetische waarden. We zullen verschillende voorstellen doen aan het inititiatief aan de hand van zowel de genoemde thema's als de uitvoeringskosten, onderhoud en uitvoerbaarheid.

Om te begrijpen welke veranderingen door omwonenden gewenst zijn hebben wij uw input nodig. Dit zal plaats vinden aan de hand van deze vragenlijst. Hierin zullen wij onderzoeken wat enkele betrokkenen belangrijke aspecten vinden die veranderd zouden moeten worden op het Transformatorplein.

De vragenlijst is geheel anoniem en de resultaten worden alleen intern tijdens het onderzoek gebruikt. Huisnummers worden gevraagd om een betrouwbaare inventarisatie te kunnen doen van de (verdeling van) verschillende opinies en het verwerken hiervan, maar zullen verder geen rol spelen tijdens het onderzoek.

De vragenlijst bestaat uit 3 vragen en het invullen duurt ongeveer 10 minuten. Wij verzoeken u vriendelijk om deze vragenlijst **vóór dinsdag 6 Oktober 2020 om 18.00u** in te vullen.

Bij voorbaat hartelijk dank!

Met vriendelijke groeten,
Het consultancy team AGORA

* Wat is uw rol op het Transformatorplein?

- ◯ Huiseigenaar
- ◯ Huurder
- ◯ Bedrijfseigenaar
- ◯ Anders

Op welk nummer woont u?

- ◯ Ik woon niet op het Transformatorplein
- ◯ 15
- ◯ 17
- ◯ 19
- ◯ 21
- ◯ 23
- ◯ 25
- ◯ 27

* **Invullen 100-punten vraag**

Voor deze vraag krijgt u in het totaal 100 punten om te verdelen over verschillende factoren die u graag zou willen zien veranderen op het Transformatorplein. De factoren die u belangrijk vindt, krijgen meer punten dan de factoren die u minder belangrijk vindt.

Voorbeeld

U vindt het verminderen van hitte een belangrijke factor die meegenomen zou moeten worden bij een ingreep in de openbare ruimte op het Transformatorplein. U kunt deze dan bijvoorbeeld 30 punten geven. Uw op één na belangrijkste factor is bijvoorbeeld dat u graag meer biodiversiteit zou willen, dus u geeft deze factor 20 punten. U heeft nu 50 van de 100 punten verdeeld, dus u heeft er nog 50 over om te verdelen over de overige factoren. Als u sommige van de factoren helemaal niet belangrijk vindt, kunt u aan deze factoren 0 punten toekennen.

Een toename in **privacy** voor bewoners en gebruikers van het plein

Een verbeterde **akoestiek** op het plein

Vermindering extreme **hitte** op warme dagen

Een betere **waterbalans**, dus minder last van droogte of juist te veel water op het plein

Vermindering van sterke **wind** over het plein

Meer aandacht voor **aesthetiek** (uiterlijk) van het plein

Meer aandacht voor **functionaliteit** (recreatie, sport mogelijkheden, plek om te zitten, etc.)

Toename in **biodiversiteit**, dus meer plant- en diersoorten

* Zou u geïnteresseerd zijn om te helpen met beheer, onderhoud en tuinieren?

- ◯ Ja, meer dan 4 keer per jaar
- ◯ Ja, tussen de 1 en 4 keer per jaar
- ◯ Ja, maximaal 1 keer per jaar
- ◯ Nee

Heeft u nog overige opmerkingen en/of ideeën?

A.2 Stakeholder Analysis (SA)

A stakeholder is any person or group that influences or is influenced by the research, has an interest in the research, or is affected by the research (Durham et al., 2014; Varvasovszky & Brugha, 2000). Including an SA in a research study is therefore needed to understand the different interests of all the stakeholders, and potentially conflicting interests (Reed et al., 2009). Furthermore, the SA aims to understand the behaviour, intentions, and interrelations of all the stakeholders (Varvasovszky & Brugha, 2000). This specific analysis is applied in many fields, such as policy, management, and project implementation. It is also increasingly being used to represent people or groups relevant to environmental decision-making processes in a systematic manner (Reed, 2008). When an SA has not been conducted, marginalised groups are in danger of not having as much of an influence as more powerful and well-connected stakeholders (Reed et al., 2009). However, when an SA has been conducted the results are useful for identifying assumptions on which the success or the failure of the project outcomes depends (Varvasovszky & Brugha, 2000). Furthermore, collaborative efforts between (non-academic) stakeholders and researchers are very valuable. They can increase ownership, legitimacy, and accountability for both the problem and the solution options (Mauser et al., 2013).

The first step to be taken is to identify the stakeholders, which is done in three stages. The three stages are: i) defining who the stakeholders are; ii) assessing, analysing, and prioritising the stakeholders; and iii) understanding the stakeholders (Durham et al., 2014). The first stage was conducted during the first three weeks of this project while writing the proposal. The identification of stakeholders was done by brainstorming on all relevant parties, as well as listing the parties mentioned by the commissioners. Assessing and analysing the stakeholders was done via the input of the commissioners as well as literature research. Prioritising the stakeholders was done via a discussion and brainstorm of the team; as well as via input of the commissioners, coach, and academic advisor. Often it is not possible to include all stakeholders, it will get too complex and time-consuming (Reed et al., 2009). The third stage was conducted via both primary and secondary sources. Understanding the stakeholders via primary sources was done via a questionnaire that was sent to all the residents and to the owner of the café. Understanding the stakeholders via secondary sources was via documents (both published and unpublished), reports, internal regulations of organisations, and policies. For the primary sources, it was important to keep culture and context in mind, to decide how to interact with the stakeholders (Varvasovszky & Brugha, 2000). In order to do this, the questionnaire was approved by the stakeholder before it was sent out to the stakeholders.

In order to be able to conduct an SA, a set of questions needs to be considered as well. These questions are: i) What are the purpose and time-dimensions of the interest?, ii) What are the timeframe and resources available?, and iii) In what contexts and at what level will the research be undertaken? (Varvasovszky & Brugha, 2000). This set of questions will be taken into account and indirectly included in the questionnaire that will be sent to the stakeholders.

Intermediate outputs can be constructed while the data collection progresses. In these outputs numerous aspects will be visible: quantification of the interests of the stakeholder, the resources and/or influence that the stakeholder can invest, the support or opposition of the stakeholders regarding possible directions, and the level of importance the researchers want to give to each of these aspects (Varvasovszky & Brugha, 2000). The researchers will analyse these outputs to eventually construct a table summarising the final assessment regarding involvement of the stakeholder, interest of the stakeholder, influence/power of the stakeholders, position of the stakeholder, and impact of the project on the stakeholder (Varvasovszky & Brugha, 2000).

A.3 In-depth Explanations for Possible Measures

A.3.1 Annual/ Perennial Flower Meadow

Figure 28 - Example of a wildflower meadow with various types of vegetation.

Flower meadows are green strips sown with a diversity of plant species (see Figure 28). These meadows provide the opportunity to increase floral complexity within urban contexts (Hoyle et al., 2018). Besides providing a beautiful sight (Hoyle et. al, 2018), these green spaces accommodate plenty of nectar to attract pollinator species when flowering. Pollinator diversity and abundance has been shown to increase with higher floral resources provision and diversity (Hicks et. al, 2016; Ketelaar, 2018). Especially flower meadows sowed with native plant species will significantly support diversity in specialistic wild pollinator species, which are of conservation concern (Ketelaar, 2018). Apart from this, when paved surfaces are transformed into herbaceous vegetated areas such as meadows, water retention will increase (Pulighe et al., 2016). The transformation also adds an overall cooling effect on the square through evapotranspiration (Lenzholer, 2015) and reduces noise through dampening (Derkzen et al., 2015).

Urban soils such as on the Transformatorplein are suitable for flower meadows because impoverishing the soil is not required before constructing the flower meadow (Vlinderstichting, 2017). Sowing needs to be done with very high densities of seeds (Dunnett & Hitchmough, 2008) and is relatively low in costs as well as easy to perform (Ketelaar, 2018). Planting would be more beneficial when the location needs to look attractive as soon as possible instead of having to wait on germination of the seeds. Another option would be to both plant and sow (Ketelaar, 2018). When selecting flowers and plants, attention should be given to the different characteristics of the site (Dunnett & Hitchmough, 2008), as well as planning for a long flowering season to lengthen the aesthetics (Ketelaar, 2018). Some experience or advice of experts is recommended. When planned and established well, flower meadows can be one of the cheapest and least demanding greening solutions regarding management (Ketelaar, 2018).

Examples of plant species one could think of that can cope with dry conditions are *Malva moschata, Anthemis tinctoria, Papaver rhoea, Anthericum lilago, Salvia pratensis Alchemilla xanthochlora, Leucanthemum vulgare,* and *Achillea millefolium* (Ketelaar, 2018).

A.3.2 Bird nesting boxes

Artificial nesting boxes for birds can be attached to buildings to support biodiversity (Figure 29). These boxes mainly work for cavity breeding birds: species that breed in tree cavities or spaces, cracks and holes in between rocks. Examples of cavity breeding species are swallows, sparrows and woodpeckers (van Heerewaarden, Zeegers, & van Kuik, 2019).

Nesting boxes are often designed species-specific; therefore, one needs to take care which species is preferred and thus which boxes are suitable as well as how far the boxes should be distanced (Vogelbescherming, n.d.). When installing a nesting box one should not place it fully in the sun because temperatures will become too high for the young birds. Optimally the box is somewhat protected by vegetation to provide cover, even though the entrance should remain open to allow a free flight route in- and out of the box (van Heerewaarden et al., 2019).

Figure 29 - Examples of bird feeding station and nesting box crafted from wood.

A.3.3 Bushes

Figure 30 - A Rhododendron bush can provide an aesthetically pleasing sight and deals well with difficult soil conditions.

Hedges and bushes are usually planted in urban environments for their aesthetic looks or to mark a boundary (Figure 30) (Blanusa et al., 2019). Besides these functions, bushes, just like trees, may also contribute to cleaner air in the urban environment by uptake of gaseous pollutants which are abundant in most urban environments. Air quality may however also become worse by adding bushes due to the emissions of VOCs (Volatile Organic Compounds) as they may form pollutants such as ozone. Through evapotranspiration and shading hedges and bushes may also contribute a cooling effect on its environment (Zou et al, 2019). Hedge species may also contribute to biodiversity in urban environments through the provision of shelter, nest sites, food resources and corridors for movement (Beninde et al, 2015). Hedges could also provide some sort of sound barrier. This depends on

biomass density, leaf size and leaf orientation (Blanusa et al., 2019). Due to their usage for boundary indication and their cover low at the ground, bushes may also provide privacy in open areas by blocking the view.

When looking at bush species, care should be taken to select bushes that are not high maintenance or invasive.

A.3.4 Free-Standing Green Walls

Free-standing green walls, or living walls, represents one of the evolutions of the classical concept of a green wall or green facade. It involves the adaptability of these concepts to a different type of surface, in this case, a free-standing structure (Manso & Castro-Gomes, 2015). The vegetation elements are allocated on a free-standing structure that can take different forms such as panels, fences, and columns, which do not need to be applied to buildings' surfaces (Figure 31) (GRHC, 2008). Combining the use of plant textures with inviting design patterns can greatly contribute to the aesthetic improvement of the square while also improving its environmental quality (GRHC, 2008). Free-standing green walls can be used in a sitting area (like the café at the Transformatorplein) to avoid prying eyes towards the windows of the buildings overlooking the square, to mitigate noise, and to create aesthetically attractive natural elements to customers (GRHC, 2008). Moreover, they can also contribute to affecting the local microclimate lowering wind velocities (Chew & Conejos, 2016). Other benefits of this structure compared to a standard buildings' green wall is the possibility to place plants on both the opposite faces of the structure. It should be stressed however, that noise reduction is not the primary function of this structure, which focuses more on privacy, temperature regulation, habitat provision and aesthetics (GRHC, 2008).

The prices of free-standing green walls vary widely and are highly dependent on the type of installation. A more complex living wall, with a higher diversity of plant species, will also result in expensive implementation and often high maintenance efforts. Besides, maintenance will be more intensive when there is no automated irrigation system, which in turn is highly costly. Implementation should be done by professionals (Manso & Castro-Gomes, 2015).

Figure 31 - Example of a free-standing green wall supported by a steel structure.

A.3.5 Free-Standing Mini Ponds

Figure 32 - A mini-pond can come in many different forms.

A study of over 80 ponds in Switzerland with different sizes showed that "a set of ponds of small size has more species and has a higher conservation value than a single large pond of the same total area" (Oertli et al., 2002, p.64). Other studies showed the importance of small ponds for the biodiversity of algae (Paczuska & Paczuski, 2015), bat activity (Heim et al., 2018; Lisón & Calvo, 2014), habitat provision and processing of carbon (Mullins & Doyle, 2019; Zamora-Marín et al., 2020), as well as the provision of drinking and foraging resources to urban wildlife (Ancillotto et al., 2019). Moreover, small, shallow and isolated ponds tend to have less fish and more vegetation biomass, making it ideal for a variety of plants, amphibians and invertebrates in comparison to larger ponds (Scheffer et al., 2006). According to The Wildlife Trusts (n.d.), plants that work well with small artificial ponds include species such as Miniature waterlily *(Nymphaea "Pygmaea Helvola"),* Lesser spearwort *(Ranunculus flammula),* Starwort *(Callitriche stagnalis)* and Flowering rush *(Butomus umbellatus).* In terms of heat stress, research showed that small ponds can relieve heat stress in urban areas during peak heat hours of the day and can increase heat stress during the evening hours (Saaroni & Ziv, 2003). However, due to the small size of the suggested pond (>1m^2), both such effects will be rather small, if even noticeable at all (Figure 32). In direct comparison to green spaces, blue spaces such as ponds and small lakes tend to be more expensive to construct and perform less beneficial in terms of relieving the UHI effect, removing air pollutants, reducing urban noise, providing recreational space and improving a city's aesthetics (Targino et al., 2019). Nevertheless, ponds seem to have an increased cooling effect when located in a windy and less sunny area (Targino et al., 2019). Lastly, mini ponds require a certain amount of maintenance throughout the year to keep them balanced and healthy, therefore it is useful to have a person who is committed to maintaining the pond throughout the year.

A.3.6 Green Rooftops

A living roof or a green roof is on top of a building and it is partially or completely covering the roof with a growing medium and vegetation placed on top of a waterproofing membrane (Figure 33). It can include further coats like a drainage and irrigation system as well as a root barrier. Green roofs are multifunctional. They can absorb rainwater, create a habitat for wildlife, provide insulation, decrease the stress levels of people living nearby by enhancing the general aesthetics, they can increase compassion, and they can mitigate the UHI effect as well as help in lowering the urban temperature. Additionally, the vegetation on green roofs is casting shades whereby cooling off the roof surface as well as cooling down the surrounding air through evapotranspiration. On hot days of the year, the surface temperature of a conventional roof can be up to 50°C warmer than the air temperature, whereas the surface temperature of a green roof might even be cooler (EPA, 2008). A wide variety of buildings can be fitted with a green roof, from private residences to industrial facilities. A green roof can be anything from a fully usable park to just a 2-inch layer of groundcover (EPA, 2008; Özyavuz et al., 2015). It must be noted that the ecosystem services provided by the roof, such as cooling effects and water retention are highly dependent on the type of vegetation, and thus the depth of the substrate, installed (Lenzholer, 2015).

Intensive roofs, with thick substrates and a lot of vegetation but providing many ecosystem services, need to be implemented on strong constructions considering the extremely heavyweight. These roofs are very costly and need a lot of maintenance. Extensive green roofs are much lighter but also provide significantly fewer ecosystem services, are cheaper solutions and may require less irrigation due to difference in drought resistance of the plants (Lenzholer, 2015).

Figure 33 - Example of a green roof with skylights and various vegetations.

A.3.7 Green Roof Carports

Carports are structures suitable for parking, partially or fully open on the sides, and that usually consists of a roof and a load-bearing structure (Özkal et al., 2016). Because of its proven properties, steel is the most widely used element in building carports. Although wood may seem aesthetically preferable, it is more fragile when exposed to weathering (Özkal et al., 2016). Carports are widely used in many contexts, even in public areas to delimit parking spaces and protect cars. They prevent damage to cars from hail, snow, rain, and corrosion (Özkal et al., 2016).

These structures are not only fixed to the buildings but can also be free-standing. This makes them a potential option to implement to green the Transformatorplein. The free space on their roof is increasingly being used as a real green roof (Figure 34) (Özkal et al., 2016). Therefore, the benefits in terms of ecosystem services, as well as maintenance needed, are similar to those of green roofs on buildings (Chapter 16.1.7). Apart from these benefits, the construction of a free-standing green roof can also provide privacy by blocking views and can serve as a wind-breaker. Costs are expected to be higher because the heavy bearing construction needs to be built as well.

In this way, the objective of making the Transformatorplein a greener area can be combined with the desire expressed by the commissioners to maintain comfortable parking areas in front of the houses.

Figure 34 - Examples of an open carport (left) and of a greened bike carport roof (right).

A.3.8 Green Walls on Resident Housing

Figure 35 - Vines and other plants like moss can grow on the facades of houses.

Green walls, or facades, use the standing structure of buildings as a platform to grow on (Figure 35). Green walls come in different forms, the most common forms include vines that grow upwards and root in the soil, plants that hang down by growing in pots or added soil on higher build places, and plants that grow upon the wall itself, which is frequently done with mosses (Sheweka & Nourhan Magdy, 2011). Plants, and therefore green walls, may have a strong cooling effect on the facades through shading and evapotranspiration (Lenzholer, 2015). Besides the cooling effect, green walls may also help with aesthetics and improve biodiversity (Collins et al., 2017). Biodiversity additions of green walls may be limited due to the minimal variety in plant species that can be used (Mayrand & Clergeau, 2018).

When constructing a green wall, attention must be given to the used materials (Manso & Castro-Gomes,, 2015). Besides, water can be a bottleneck to the survival of plants; in dry periods they need to be irrigated (Lenzholer, 2015). Although some green walls may grow without any additional materials due to the plants hanging or climbing by themselves, others may need a framework to support the vegetation and give a tougher structure to the entire green wall and prevent it from falling off. Besides, a supportive system may also prevent the roots from entering the building material. The implementation of a framework is often done by professionals. The estimated costs are highly dependent on the type of facade installed; ranging from relatively cheap for plants climbing themselves, to more expensive for climbers that are supported and very costly when installing green tapestries (Lenzholer, 2015).

A.3.9 Insect Hotels

Figure 36 - Examples of insect hotels arranging a wide array of materials in different ways.

A relatively easy and cheap possibility, especially when handmade, to support biodiversity is the creation or placement of an insect or bee hotel. Besides supporting biodiversity, insect hotels can contribute the aesthetics when neatly constructed (Ketelaar, 2018). Additionally, when signs are provided that explain the purpose of the insect hotels, viewers can be educated about them.

This measure will especially work well in combination with a flowering meadow, thus when both resources and habitat are provided to insects (Ketelaar, 2018). When constructing an insect hotel yourself, different (scraps of) materials can be used such as bricks, bamboo, old wood, clay or loam. By making holes with different diameters and placing all of the materials in a frame (such as in Figure 36) these hotels can provide habitat to different species of insects. The hotels should be placed as much as possible in the sun (facing the south) and preferably without too much interference of the wind or rain to prevent weathering. Also, the hotel should be left in the same place during the winter to leave hibernating animals (van Breugel, 2017). After a couple of years, the materials in the hotel will have to be refilled; complete renewal would damage the species residing, and therefore it is recommended to just add new materials but leave the rest.

The hotels can be bought for different prices depending on the size, starting from tens of euros to hundreds of euros for bigger ones. One very important aspect to give attention to, is to select for a professionally made insect hotel, as many are being sold that do not fit the requirements and will thus not provide habitat to insect species. The Vlinderstichting gives an extensive explanation on what to look out for when purchasing an insect hotel:
https://www.vlinderstichting.nl/actueel/nieuws/nieuwsbericht/veel-slechte-bijenhotels-in-omloop.

A.3.10 Larger tree species

Besides the aesthetical contribution of large trees, they can positively impact the urban environment by cooling during hot summer days (Liverley et al. 2016). The cooling effect is caused by a partial reflectance of the irradiance, transpiration through the leaves, and providing a cooling shade for the underlying ground or stone (Nowak, 2002). The shadow reduces incoming solar radiation up to 50% (Lenzholer, 2015). However, a large percentage of canopy in an area may prevent mixing of air above and below the tree, resulting in hotter air becoming trapped under the canopy (Figure 37) (Nowak, 2002). Due to this trapped air, the cooling effect of tree shade and transpiration may not always compensate. Large trees also contribute to the reduction of several gaseous pollutants from the air in an urban environment (Nowak, 2002). Some of these pollutants may be removed by uptake of the trees, while others are removed by the plant surface. Trees in urban areas may also emit VOCs (Volatile Organic Compounds) which may contribute to the formation of ozone and carbon monoxide under higher temperatures in combination with higher nitrogen oxide concentrations. Moreover, large trees have a positive impact on urban biodiversity (Wood, 2020). Depending on the tree species, bird species and insects are attracted to the ecosystem created. Additionally, trees can provide privacy to open spaces as the leaves can block views, they can break winds on squares and dampen noises with their leaves.

Trees species should be selected well before planting to increase success, as stress in urban environments can lead to illnesses. Moreover, they should be configured well so activities on the location can continue. The price of planting is highly dependent on the size of the tree; larger trees will add up to ecosystem services sooner but are also more expensive and more complex to plant. Moreover, trees do need occasional management such as pruning (Lenzholer, 2015). Tree growth on the Transformatorplein may also be limited due to the soil and groundwater pollution as they generally grow deep roots which will be able to reach the ground underneath the remediated soil.

Figure 37 - Examples of tall trees to be planted at the Transformatorplein: Fraxinus Excelsior (left) and Tilia Tomentosa (right).

A.3.11 Modular Wire-cube Structure with Living Plants

Figure 38 - Modular Wire-cube structures can be arranged in many different ways, vertically and horizontally.

These Urban Green Infrastructure consist of a skeleton of cubic wire modules suitable for housing living plants (Figure 38). The cubic modules that make up this self-supporting structure are pre-cultivated to allow the vegetation to develop more rapidly and immediately starting to provide benefits in the urban area of interest (Connop et al., 2016). Modular living structures are elements with a specific dimension that include in their thickness the medium (soil) that allows the plants to take root and grow (Manso & Castro-Gomes, 2015). This modular structure is perfect for urban environments, it does not require huge spaces and allows the design of the structure to be adapted to the characteristics of the installation area. The result is a three-dimensional urban space that provides multiple vegetation-based ecosystem services.

Moreover, these elements enhance shade and shelter areas. Usually, plane trees (deciduous tree) provide a lot of shade and are the most effective species of trees for such types of green urban infrastructure. Therefore, by exploiting the versatility of these modular structures it is possible to create green oasis even in urban areas characterised by heavily paved surfaces (Connop et al., 2016). Another advantage of such modular structures is that they give the possibility to choose whether to place the vegetation elements on all sides or only on one side. In this way, they can be used both as a free-standing structure and as a structure to be used on the facades of buildings (Connop et al., 2016).

It should be noted that the entire system is rain-fed (Connop et al., 2016) thus the system only needs the addition of nutrients. Maintenance may consist of replacing dead modules or plants, monitoring, providing nutrients and weeding. Prices are expected to be quite high (comparable with that of a complex green wall) and dependent on the type of modular system installed, as well as the plant species used.

A.3.12 Outdoor Furniture

Street furniture contributes to the functionality of a public square. It provides a place to rest, recharge and connect (Coolen & Meesters, 2012; van Lieshout & Aarts, 2008; Lee et al., 2015). Adding benches around one or multiple tree trunks on the Transformatorplein will enhance people's experience of the square.

Figure 39 - Example of a wooden bench built around a tree trunk.

When selecting for a durable material, maintenance costs and effort will be low. Outdoor furniture made out of wood will demand more maintenance than plastics (Lenzholer, 2015). Prices for outdoor furniture found online range from a couple of hundred to a couple of thousand euros, depending on the type, design and material used. It is recommended to use a bench that is made of a low-conductive material like teak wood and looks similar to the one displayed in Figure 39. The type of bench recommended is inviting people to enjoy some time in shaded outdoor areas. Additionally, the missing back incentivises people to only take a short break from their endeavours (Yücel, 2013).

A.3.13 Permeable Surfaces

Research has shown that permeable surfaces for parking lots, such as grass blocks, can provide a solution to the urban issue of water retention, noise pollution and stormwater management (Figure 40) (Bhandari et al., 2018). Additionally, permeable surfaces can reduce the heat island effect in urban areas during the summer and delay freezing during the winter months (Novo et al., 2013). However, combining grass blocks and grass surfaces with other regular bricks or permeable surfaces can increase the capacity of the area to bear vehicles and heavy loads (Guo & Liao, 2019).

One can expect that permeable materials used for surfaces may need replacement sooner than impermeable materials even though it will still last for a long time due to accelerated weathering (Scholz & Grabowiecki, 2007). Moreover, prices found online show prices below €10 per square metre, and reflect that overall grass block pavers seem to be a bit more expensive than permeable bricks.

Figure 40 - Permeable bricks can have a hole in the centre, allowing grass to grow.

A.3.14 Rain Garden

Rain gardens are lower elevated areas that have been planted with grass and vegetation to temporarily store water (van Boxtel, 2020). Main functions of a rain garden are infiltration of rainwater into the soil, interception of rainwater by the vegetation, evaporation of rainwater, and the transpiration of rainwater via vegetation (Muthanna et al., 2008; Nemirovsky et al., 2015). They are local small-scale stormwater management systems that are aimed at restoring the hydrologic cycle that has been disrupted by development while utilising natural processes (Nemirovsky et al., 2015; Nichols & Welker, 2018). At the same time, they provide additional environmental benefits, and they are also a way of increasing the aesthetics and habitat functions in the urbanised area by planting taxonomically diverse vegetation (Shuster et al., 2017; Nemirovsky et al., 2015; Yuan et al., 2017). Several studies have already shown the effectiveness of rain gardens in retaining stormwater runoff, from a variety of sources (e.g. buildings, roads, car parks) (Yuan et al., 2017). Studies show that peak runoff is reduced compared to the peak inflow when rain gardens are present, and there is an average delay of 5.5 hours for the runoff flows into the combined sewer system (Yuan et al., 2017; Shuster et al., 2017).

Conventional rain gardens consist of vegetation in a lower elevated area where water can accumulate if needed, a mulch layer, and sandy loam soil (Figure 41). The advantage of the mulch layers is its high capacity to absorb pollutants, but the mulch layer is not strictly necessary (Nichols & Welker, 2018; Muthanna et al., 2008). There are two types of rain gardens: lined and unlined. A lined system is needed when the underlying soil is polluted, an impervious layer will then be needed, and the water will be collected with an underdrain and removed from the system. An unlined system does not have an impervious layer underneath, so the water flows through the soil into the underlying layers (Muthanna et al., 2008). An important thing to note is that lined systems are more complex and expensive to install than unlined systems (Nemirovsky et al., 2015).

The effectiveness of a rain garden depends on the vegetation and soil. Native vegetation is typically used (Nemirovsky et al., 2015), but studies have found that specifically selected species might be better to use. A good option is to use so-called forbs, which are non-grass herbaceous flowering plants. Using a taxonomically rich variety of forbs as well as some grasses will create a plant community with a high plant density and also visual interest throughout seasons. Important factors in favour of using such a variety are that it offers more interception because there are overlapping canopies, and there are different root structures that allow water storage in a wider range of pore sizes and depths in the soil. A study in 2017 found the following list of plants to be very effective: i) *Amsonia tabernaemontana var. salicifolia*, ii) *Astilbe*, iii) *Calamagrostis brachytricha*, iv) *Filipendula purpurea*, v) *Hemerocallis*, vi) *Iris sibirica*, vii) *Molinia caerulea*, iix) *Rudbeckia fulgida var. deamii*, ix) *Sanguisorba tenuifolia*, amd x) *Veronicastrum virginicum* (Yuan et al., 2017). When constructing a rain garden, a landscape designer or gardener should be hired to help pick the most effective site, plants and design (Cost Helper, n.d.). The vegetation will also dampen sounds, thereby contributing positively to the noise pollution aspect. As mentioned before, grass will contribute to a noise reduction of 3 decibels. The exact noise reduction of other types of vegetation is still uncertain (Bolund & Hunhammar, 1999).

Costs for rain gardens consist of investment costs, operation and maintenance costs, and opportunity costs of the land use (Siwiec et al., 2018). Costs for materials range from about €10 to about €50 per m^2 when doing it yourself, and the costs for professional installation range from about €100 to about €200 per m^2 (Cost Helper, n.d.). After construction of the rain garden, it needs maintenance similar to parks, so watering during dry periods, weed control, and fertilisation if needed (Siwiec et al., 2018).

Figure 41 - Examples of rain gardens at various stages: planning and planting (left), and full-grown (right).

A.3.15 Rainwater Tanks

Rainwater tanks are a measure that can be used to catch and store rainwater. The rainwater flows from the roofs of buildings through the gutter into the rainwater tank. Previous studies have shown that people will be more likely to install a rainwater tank if they believe that rainwater tanks can help reduce the threat of water scarcity, if the time, effort or financial costs are not too large, and if they believe that they are capable to install a rainwater tank (Sharma et al., 2015). Other studies have concluded that above-ground rainwater tanks have become very popular in urban areas, due to their relatively low cost and simple systems which allow for residents to collect and use rainwater for localised applications by installing a tap in the rainwater tank to easily extract water, where there is no requirement for high water quality. Furthermore, studies have found that if residents feel that they are able to do the maintenance themselves, they are more motivated to carry out maintenance (Mankad et al., 2014).

Installing the rainwater tanks is very easy (van Veen et al., 2018), and many different shapes and sizes are available (Figure 42). Rainwater tanks can be made from wood or plastic, but the wooden variety might get damaged in the winter due to freezing. Prices of rainwater tanks range from €23 to €495 (Arnhem Klimaat Bestendig, Regenton 2020). A general point to keep in mind when purchasing a rainwater tank is to buy one with white colour because this keeps the water cool during the summer months (ATA, 2018). It is also advisable to place the rainwater tank at a shaded location, this will keep the water as fresh and clear as possible. In order to avoid mosquitoes, the rainwater tank should be covered with a lid (van Veen. et al., 2018). These lids cost around €30 (Arnhem Klimaatbestendig, Regenton 2020). When installing the rainwater tank, it is important to place a filter, this ensures that only the rainwater ends up in the rainwater tank and leaves and pollen are filtered out (ATA, 2018). So-called first flush devices should also be installed, these are small tubes that fill up with the first amount of water. This first amount contains possible bird poop etc. that was present on the roof or in the gutters, which you do not want to end up in the rainwater tank (Moglia et al., 2013).

As for the necessary maintenance, this can be divided into categories. First off, some maintenance needs to be done every three months. This includes inspecting and clearing the gutters and the filters of the rainwater tank. Secondly, every six months the roof needs to be checked for defects, overhanging branches must be removed, and the tank and lid need to be inspected for defects. Annually, the tank needs to be checked to make sure that its structural integrity is still good. And finally, every two to three years the sediment level in the tank needs to be checked, and if necessary the accumulated sediment needs to be removed (Moglia et al., 2013; Mankad et al., 2014).

Figure 42 - Examples of rainwater collection tanks gathering water from various roofs.

A.3.16 Raised Planting Bed with Vegetation

Figure 43 - Examples of raised beds with different themes: flowers (left) and food (right)

Raised beds are a measure which can be used to raise the vegetation above the contaminated soil or separate the vegetation from the contaminated soil entirely (Clark et al., 2008). Raised beds may provide a new layer of clean soil above the contaminated soil allowing plants to grow freely (Figure 43). Without any countermeasure to prevent spread from contaminated soils the clean soil layer may become contaminated again (Clark et al., 2008). Remediation of the soil and separation of said soil from other contaminated areas could be a good measure to prevent the raised bed from becoming contaminated.

Providing raised beds which are separated entirely from the contaminated soil could be another way of providing arable soil in a contaminated urban environment (New, 2015). Large "Planting pots" with nutrient-rich soil may provide new possibilities for plants to grow in contaminated areas. The soil in the plant pots will not be in touch with the contamination allowing the soil to remain clean. The raised

planting beds may be used for diverse flowering vegetation that contributes to an increased presence of insects and possibly birds and adds to the aesthetics of the space (Claessiens & Dirven, 2010). Additionally, through signs explaining the purpose of the raised beds, viewers can be educated about their benefits.

Using raised beds in separate containers requires some thought about the used materials and functionality of the container. Different materials may be used for separate plant containers (Stijger, 2019). Metal materials come in different forms with Zinc, Steel and Aluminium being the most common. Metal materials are durable and require little maintenance but don't isolate against frost during colder periods. Adding an insulation layer to protect roots against frost in metal containers is highly recommended.

Plastic plant containers are lightweight and can be easily moved if needed. There are varying qualities in plastic containers with cheaper containers being much less durable against the climate. More expensive versions of plastic containers exist and are much more durable (Stijger, 2019). Plastic containers do not generally isolate too much and require an insulation layer to protect plant roots from frost in colder periods. Most expensive plastic containers have this layer included.

There are several "stone" versions of plant containers like fibre stone, fibre clay, or concrete. Fibre stone and fibre clay containers are lightweight but strong. These containers are rather durable since they do not absorb water, protecting them from frost damage. Concrete is a common material used for plant containers. It is a durable material which can be shaped easily. Concrete containers do have a problem with frost damage as water may infiltrate cracks in the concrete, expanding them during colder periods. The last material which may be used for plant containers is wood. Wood gives the container a natural look. Depending on the type of wood used the container may be very durable. To achieve this certified hardwood with a high durability class is recommended (Stijger, 2019).

Good drainage is recommended in plant containers, as heavy precipitation may cause an oversaturation in the soil causing plants to die. If a drainage system is not provided with a simple hole at the bottom may be used to allow an excess of water to escape through said hole (Stijger, 2019). Besides drainage, water retention is also important. Good water retention decreases the need for manual watering and reduces labour costs for maintenance. Water retention may be increased by adding an overflow pipe to the drainage hole (Stijger, 2019). This way water will be drained when a certain water level is reached and not before, thus increasing the amount of water stored during periods with a precipitation excess. Another measure which can be taken is the addition of water-retaining granules to the soil of the plant containers (RHS, 2020). These granules take up water during an excess and discharge the stored water during dryer periods.

A.3.17 Trees on Parking Lot and Tree Trenches

At the moment the parking lot on the Transformatorplein is a large paved area with nothing in place to break up this large impermeable area. The sun can shine uninhibited on a large part of the square and rainwater can hardly infiltrate to the subsoil. Increasing the number of trees in the paved area can solve some problems associated with the paved area. Trees induce shading on the square and cause evapotranspiration, reducing sunshine reaching the pavement and cooling the surrounding air respectively (Mullaney, Lucke, & Trueman, 2015). This can increase the thermal comfort on the square and the surrounding buildings, reducing the need for cooling in these buildings (Akbari, Pomerantz, & Taha, 2001). Moreover, planting trees throughout the parking lot area can help with heavy rainfall as well. Tree canopies intercept rainwater during heavy precipitation events and the areas where trees are planted allow for infiltration in the soil (Zabret & Šraj, 2019). This measure could also break up the

monotonous flat parking area of the square to increase aesthetics on the Transformatorplein, with the eastern part in particular.

To reduce complexity it is recommended to plant one tree species. This will make it easier to maintain the area around the trees in autumn (as trees lose leaves simultaneously) and saves costs. Costs of planting are highly dependent on the age and species of trees planted. If different species of trees are used, this window can be up to two months instead of a few weeks, and even longer when planting oaks or copper beeches. Recommendations regarding street trees from tree nurseries and landscape architects, however, often already exclude shallow rooting trees (Der Kleine Garten, n.d.).

A frequently used tree species on parking lots is the plane tree (*Platanus hispanica*), which is resistant to car exhaust fumes, otherwise polluted air and particulate matter. Furthermore, it is insensitive to the paved surfaces around it. The branches of the plane trees rarely break off and by pruning them, wide, shady crowns can be created. Apart from its functional properties, the maple-leaved plane tree is also visually attractive with its light green foliage and the peeling bark in the autumn that creates an interesting pattern on the trunk. The peeling of the bark also serves as a protection against heat from the winter sun, which is reflected on the light bark. In terms of biodiversity, the plane tree does not have a lot to offer but in combination with other greening measures, this can be compensated. Overall, the tree does not necessarily provide a biotope but can filter a lot of dust and enhance the microclimate on the square (Der Kleine Garten, n.d.).

Other tree species that have shown some success over the last few years in parking lots include *Tilia tomentosa* (silver lime) due to its ability to turn over its leaves on sunny days to reflect more light with the lower silver side of its leaves, the trident maple tree (*Acer buergerianum*) due to its ability to handle frost and drought well and the oriental plane tree (*Platanus orientalis*) due to its robustness towards diseases (Knauer, 2019).

Tree trenches

Figure 44 - An example of a tree trench.

Tree trenches are a way of implementing trees in parking lots as mentioned above (Figure 44). The innovative part about this measure is the permeable pavement lying on a permeable substrate that allows more water to reach the tree while sacrificing less surface area for parking. Benefits are similar to the inclusion of trees in regular planting boxes like mentioned above. The increased infiltration through the permeable pavement can help with preventing drought stress in the trees while taking up less room on the square (Brattebo & Booth, 2003).

If this smaller footprint is preferred, implementation will be more complicated and a lot more expensive due to high implementation costs and materials (including the trees). Especially when a drainage system needs to be added, when a fast discharge of water through the system is necessary, the costs are expected to increase a lot.