A Green Heart for Amersfoort

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Abstract

The aim of this research project is to make the city centre of Amersfoort a 'place to be' by greening the main shopping streets. The city centre is experiencing consequences of climate change and urbanisation, including local floodings, periods of intense heat, and decreasing biodiversity. Due to the rise of online retail, consumers are increasingly going to the city centre for the experience, urging urban shopping areas to invest in enhancing the attractiveness of public spaces. However, factors such as stakeholder viewpoints, regulations, and the underground infrastructure need to be considered when proposing interventions.

This research focuses on implementable innovations for the Langestraat and Krommestraat of Amersfoort to reduce the effects of climate change taking various aspects and stakeholders of the city centre into account. Therefore, the main research question is: Which green innovations are best suited for improving water management, biodiversity, heat stress management and attractiveness of the Langestraat and Krommestraat in Amersfoort, which are viable when considering current challenges, limiting factors in the immediate surroundings and different stakeholder viewpoints?

To answer the research question, extensive literature search and qualitative research in the form of interviews with stakeholders and experts were conducted. Semi-structured questionnaires were either sent to the respondents or discussed in one-on-one interviews. Stakeholders collectively wish for a greener and more biodiverse urban environment. They support green solutions for climate change and emphasize positive health effects as well as the attractiveness of greening, while highlighting challenges such as maintenance, car-traffic, and bike-related issues. The identified primary challenges are heat stress, extreme precipitation, biodiversity loss, and the impact of online shopping on urban retail. The most significant limitations are the current infrastructure, transport, and traffic related issues within the city centre. Urban green spaces, including street trees, play a crucial role in enhancing human well-being and satisfaction in cities.

The following green innovations were considered most relevant: Street trees, climbing plant structures, façade gardens, shrubs, plants and grass, planters, infiltration crates, infiltration strips, and a drainage transport (DT) and infiltration transport (IT) sewer system. The cables underground permit planting trees on parts of the street.

Future research should build upon these findings to enhance the comprehension of appropriate green innovations for Amersfoort, focusing on aligning the innovations in the Langestraat and Krommestraat with the city's broader green infrastructure. Additionally, further investigation is needed to assess the drawbacks and financial implications of green innovations.

Advice

The city of Amersfoort is changing. The shift to online retail pressures the city centre to change from a place to buy to a place to be. Due to climate change the city centre will become less pleasant, especially paved shopping streets without greenery, such as the Langestraat and Krommestraat. Increased heat and rainfall events, will plaque residents, shop owners, visitors, and customers, together with an increase in biodiversity loss and a decrease in overall well-being. To fight this, we should make these streets part of the green heart of Amersfoort and implement green measures to make Amersfoort an attractive place to be.

Amersfoort is already a lively and attractive city with a lot of heritage, but implementing more green space in urban areas can improve the city further. Aspects, such as heat and water management, biodiversity and attractiveness can be improved via green innovations. Not only will green space contribute to increased happiness, satisfaction and spending of visitors and customers, but can also contribute to overall well-being of residents, shop owners, visitors, and customers by reducing stress and improving mental and respiratory health.

When interviewing stakeholders in Amersfoort, it became clear that besides the Ondernemers Binnenstad Amersfoort (OBA) and municipality, the residents of Amersfoort are also dedicated to change Amersfoort into a place that is better prepared for climate change, with a more attractive appearance. Furthermore, the OBA's goal to make the experience of visiting the city centre more diverse is in line with the desire of the residents and shoppers in Amersfoort to make the city centre a place to stay.

Limiting factors and challenges

To realize green innovations limiting factors must be considered. The most important aspects of this are described below.

Underground infrastructure

Under the paved streets of the Langestraat and Krommestraat, many cables and pipelines are laid. These include electricity and data transport cables, gas & oil, drinking water, and sewer pipelines. To consider green innovations, it is important to know the layout of this underground infrastructure. This is especially important when planting trees, since tree roots are opportunistic and can grow to depth and widths that could risk contact and damage with underground infrastructure and makes maintenance harder. Therefore, we constructed a map that indicates available area on the Langestraat that allow the planting of trees considering the underground infrastructure as well as the root space the tree needs to grow well.

The map below shows that with the cables and pipelines there is still enough place to plant trees in the Langestraat. In the Krommestraat there is no space for the trees underground.

Soil characteristics

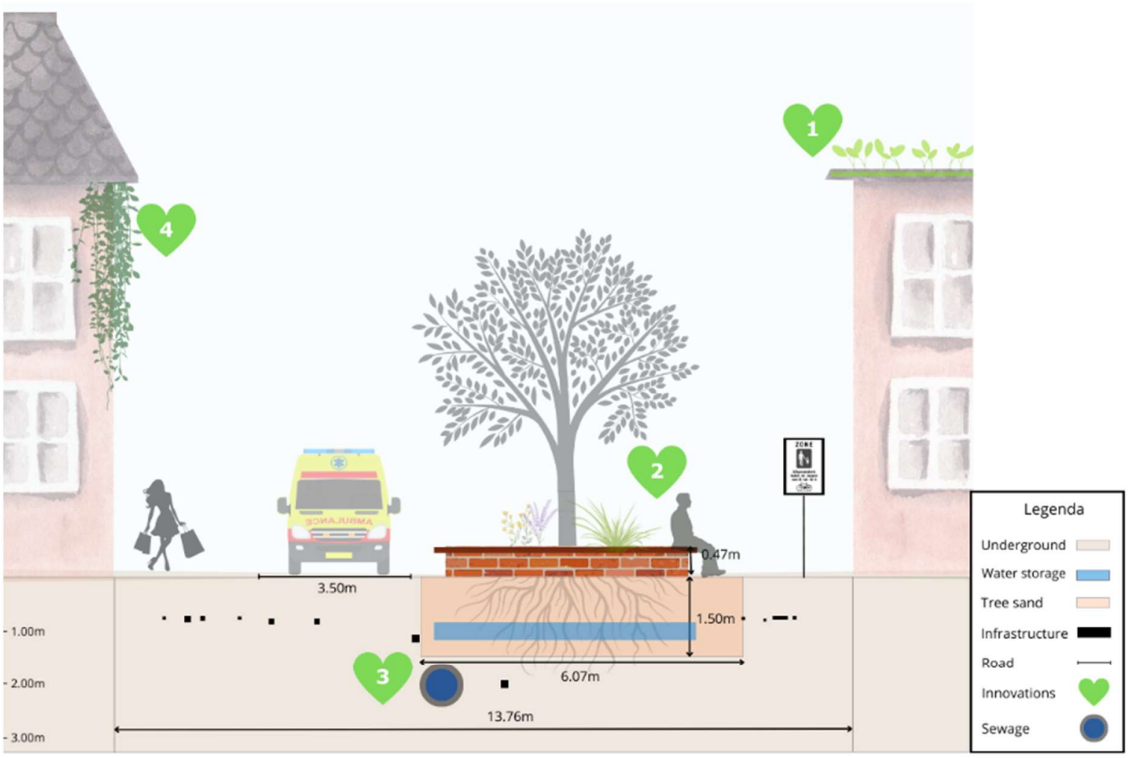
The soil under the city centre of Amersfoort consists of sand. Sand is low in nutrients as well as more permeable than other soil types, which means that water will infiltrate relatively quickly. This means that the ground is currently not optimal for trees and other vegetation.

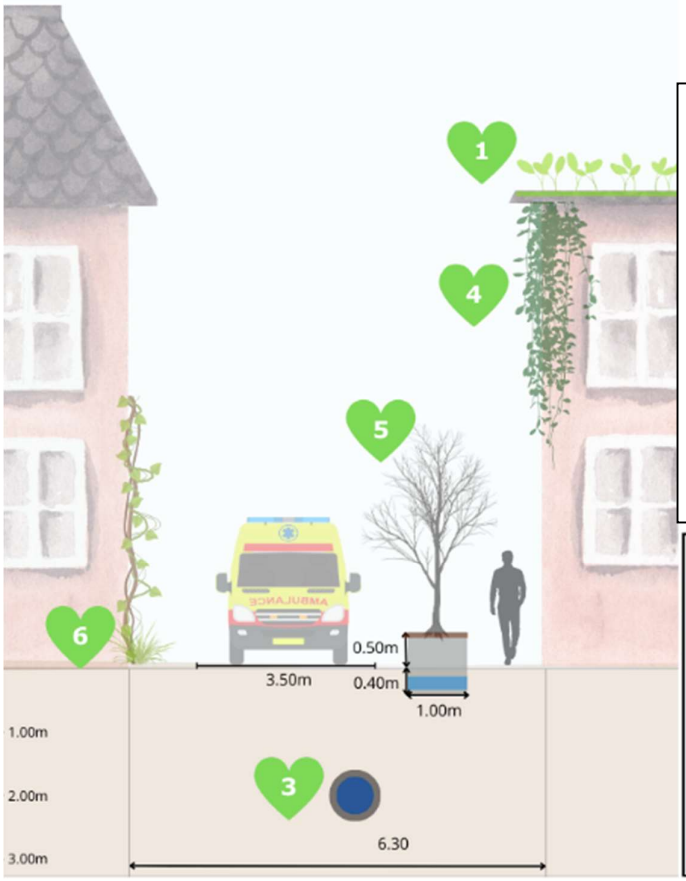
Policies

The streets today allow multiple modes of traffic, including pedestrians, cyclists, vehicles for loading and unloading, emergency vehicles and garbage trucks. Especially space for loading and unloading and parking space for bicycles take up available space for greening.

Furthermore, many of the buildings in the Langestraat and Krommestraat are monumental and protected by heritage regulations. These regulations should be carefully checked to implement green in the Langestraat and Krommestraat.

Our vision





Our vision of the Langestraat (Above) and the Krommestraat (Left).

1: Green Roofs.

2: Line of Trees.

3: Combined Sewers with Hollow Road

4: Hanging green Facades

5: Trees in Planters

6: Façade Gardens

Our vision of the Langestraat and Krommestraat uses multifunctional greening to make the city more attractive and liveable. In our vision the underground infrastructure, limited space and needs of plants are considered. This makes sure that there is enough room for emergency vehicles, and plants will grow healthy while the city continues to thrive.

In our vision on the previous page, the following measures are presented:

1: Create green roofs on flat or slightly slanted roofs. These green roofs capture and hold rainwater to reduce water runoff into the streets. They also function as a hub for biodiversity and cool down the buildings they are placed upon. To create a green roof, weak roofs need to be reinforced and its monumental status needs to be considered.

2: Plant a line of trees in the ground where the underground structure allows it. The trees used stay compact to the space allocated so they do not grow too big and have compact canopies. The trees provide shade for cooling as well as increase attractiveness. To realize this successfully, you need 1 meter of fertile soil underneath the tree and place infiltration crates underneath this fertile soil. These infiltration crates capture water during rainfall events and store it to be used by the trees during droughts. This ensures that the trees stay healthy.

Around the trees shrubs, herbs, and grasses, among which a variety of nectar producing flowers should be planted. This will greatly increase the attractiveness for customers and improve biodiversity. Seating area is incorporated into this design by creating an elevated border which will make customers stay longer.

Trees implemented with this system will create a return of investment of €2,14 in ecosystem services while trees without this system would only create a return of €0,18 in ecosystem services per €1 invested.

3: Change the sewer system from combined to a separate system together with a hollow street. This increases the dispose rate of water during heavy rainfall and decreases its water pollution which decreases water treatment costs. Besides creating a separate sewer system, the stormwater system can be semi permeable, thus allowing stormwater to infiltrate into the soil in order to be used by plants.

4: Create hanging green facades that are attractive for customers. The green facades cool the building which reduces energy consumption during the summer and without restricting the usage of space or view on the shops. These green facades can be made with planters hanging down.

5: Make semi buried but movable tree planters. These trees are smaller than the trees in the Langestraat but provide similar benefits. Placing them in movable planters enables the municipality to move them out of the way when needed. On the bottom of the planters, infiltration crates are placed to store water during rainfall events and provide the tree with water during droughts. This ensures that the trees stay healthy and reduce maintenance costs. These planters are designed to provide seating spaces for visitors.

6: Develop façade gardens with sturdy climbing plant structures. In the façade gardens shrubs and flowers will be planted together with climbing plants that fill the climbing structure. This provides customers with attractive green and cools the building.

Final advice

We believe that there are great opportunities available to green the city centre of Amersfoort. As long as all parties are willing to collaborate and contribute, limitations can be overcome, and the city centre of Amersfoort can evolve from a place to buy to a place to be.

List of definitions

- Innovation - "a new idea or method, or the use of new ideas and methods" (Cambridge Dictionary, n.d.-b). This definition is interpreted in a way that if an idea or method is applied to a different location (Amersfoort) it is also considered an innovation.
- Greening – "the process of making somewhere greener by planting grass, trees, and plants there." (Cambridge Dictionary, n.d.-a).
- Green innovation – "all type of innovations that contribute to the creation of key products, services, or processes to reduce the harm, impact, and deterioration of the environment at the same time that optimizes the use of natural resources" (Leal-Millán et al., 2017).
- Flooding – An overflow of water on usually dry land caused by rain.
- Future-proof – An object being able to sustain itself in the future.

Acknowledgement

We would like to take this moment to thank our commissioners, Viola Bennink and Fokke de Jong from the Science Shop, who greatly supported us during this project. We are grateful for the opportunity to work together closely with them, and their guidance and encouragement ensured that we stayed on track to achieve our goals. We also want to thank our academic advisor, Joop Spijker, whose expertise and advice significantly contributed to the quality of our project report. We want to express our gratitude to Theo Miltenburg from the OBA for the enthusiasm with which he shared his knowledge of Amersfoort. His insights and contributions played a significant role in shaping our understanding of the local context, enhancing the outcome of our project. Lastly, we want to thank our coach Saskia Leenders-Pellis for her dedication and guidance of our team. Her encouragement and mentorship were invaluable, and we are grateful for her dedication to our team's success.

Table of Contents

1. Introduction

1.1. Environmental concerns

1.1.1. Climate change

Climate change has been a pressing concern for a long time. The Intergovernmental Panel on Climate Change (IPCC) has documented the current state of climate change in 2023. The influence of humans has contributed to the warming of the atmosphere, oceans, and land. The sea level has risen by 0.20m and the earth's climate has changed, resulting in more extreme events such as heatwaves, heavy precipitation, and droughts (IPCC, 2023). Climate change affects several areas, including nature, human health, and infrastructure (UNEP, 2017). Multiple global impacts of climate change are depicted in Figure 1. The Urban Heat Island (UHI) effect amplifies excessive heat, particularly in urban areas.

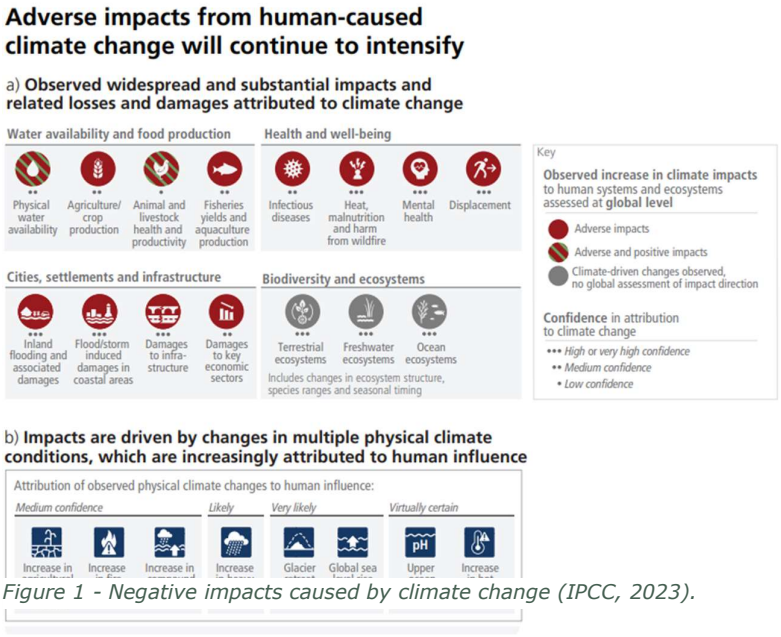


Figure 1 - Negative impacts caused by climate change (IPCC, 2023).

The UHI effect is caused by the paved areas in cities, leading to an increase in heat during the day. Furthermore, a lack of vegetation lowers the ability for heat to be absorbed in urban areas. Because of the retention of heat, heat stress occurs at night. (Deilami, Kamruzzaman & Liu, 2018; Thorsson et al., 2010, as cited in Hersbach, 2022). The effect of the UHI on humans can results in heat stress. A strong relationship between rising temperature and mortality has been shown, particularly in areas with temperate climates, due to worse adjustment to heat (Harlan & Rudell, 2011). The impact of heat on human health will therefore only increase, considering climate change (IPCC, 2023). UHI will cause many heat-related health issues to appear first in urban areas. Especially extreme heat events like heat waves will lead to health effects including dehydration, heat strokes, and fainting. Furthermore, existing medical problems like asthma and allergies can be worsened due to heat (Shahmohamadi et al., 2011).

Another issue resulting from climate change in urban areas is flooding. Climate change will increase the frequency of high precipitation events, while urbanisation will increase the inflow of wastewater into the combined sewer system (Ten Veldhuis et al., 2010). During high precipitation events, it can occur that a combined sewer system is not able to match the capacity necessary to discharge water, which will therefore result in Combined Sewer Overflow (CSO). Due to the mixing with wastewater, floods occurring through CSO can bring issues regarding human health. CSO discharges can contain infectious pathogens that come from human faeces and organic waste present in wastewater. These pathogens can cause infection in humans (Botturi et al., 2021; Owolabi et al., 2022).

1.1.2. Air quality

Air quality can also have a negative effect on human health. The air quality in urban areas in the Netherlands has been an issue for many decades, and signs of improvement have been shown. However, limits set by the Air Quality Framework Directive are still exceeded frequently, especially by Nitrogen Dioxide (NO_2) and Particulate Matter (PM) (Ascenso et al., 2021). Both pollutants can cause problematic health effects. PM can cause cardiovascular and respiratory diseases, as well as cancers (WHO, 2022). Furthermore, NO_2 causes multiple health effects including inflammation of the airways, increased asthma effects, and respiratory diseases (American Lung Organisation, n.d.).

1.1.3. Biodiversity

Biodiversity is important to the functioning of mankind. It provides mankind with economic, environmental, health, and cultural benefits (Faeth et al., 2012; Habibullah et al., 2022). Unfortunately, the biodiversity of the planet is decreasing. Between 1970 and 2016, the population sizes of amphibians, birds, fish, mammals, and reptiles decreased on average 68%. This can largely be attributed to factors related to climate change and is only expected to decrease more in the coming years (Habibullah et al., 2022). The biodiversity in urban areas is low compared to surrounding land. It is shown that the biodiversity of terrestrial vertebrates, native plants, and birds decrease in species richness (Faeth et al., 2012). A lack of biodiversity, especially biodiversity above ground, can negatively impact human health. Evidence shows that people notice the richness of species in an area and that this richness improves both physical and physiological wellbeing of humans (Fuller et al., 2007).

Although biodiversity in the soil does not directly influence human health, it is equally important as the biodiversity above ground. The soil has a microbiome, which consists of macronutrients, micronutrients, microorganisms, and other elements that are vital for plant growth and animal life. The microorganisms are responsible for the soil's organic carbon cycle. They also have a key role in climate feedback, producing or consuming greenhouse gasses such as carbon dioxide, methane, and nitric oxide. The concern that arises is the chance that this feedback can have a positive or negative impact on climate change (Jansson & Hofmockel, 2020). Part of the soil microbiome of urban areas are pollutants, for example heavy metals and polycyclic aromatic hydrocarbons. These heavy metals put a constraint on the growth of plants and affect the soil microbiome negatively (Guilland et al., 2018).

1.2. The future of shopping

In 2023, more than half a billion people in Europe used online retail and this number is estimated to rise in the coming years (Statista, 2023a). Among Dutch consumers, this increasing trend of online shopping can also be observed. The Netherlands has the seventh-largest e-commerce market in Europe with more than three percent of its GDP attributed to online retail activities (Statista, 2024). The total revenue of e-commerce sales in the Netherlands has increased from 2.82 billion euros in 2005 to 33.3 billion euros in 2022, Figure 2 (Statista, 2023b). In 2023, over 90% of individuals in the Netherlands made online purchases for personal use. Online shopping was particularly prevalent among Dutch consumers between the ages of 25 and 64, while it was less frequent among older generations (Statista, 2023d). The most popular products to buy online are clothing, shoes, and accessories for both men and women (Statista, 2023c).

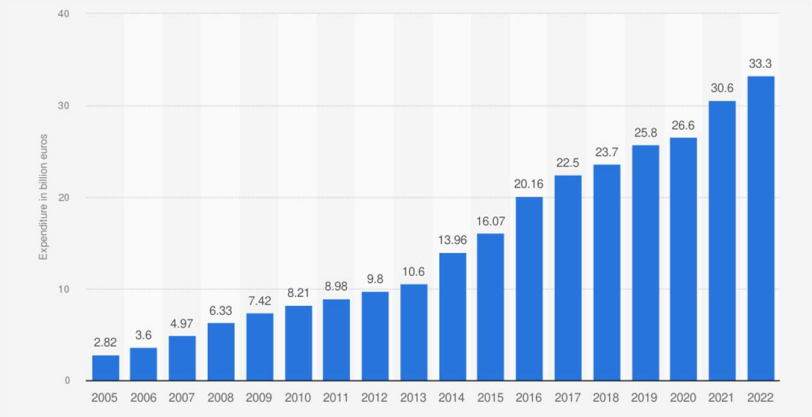


Figure 2 - Total revenue of e-commerce sales in the Netherlands from 2005 to 2022 (in billion euros) (Statista, 2024).

In a survey among Dutch consumers, 46% of the respondents indicated that a leading reason for them to prefer shopping online is that it can be done from the 'comfort of their own home'. 'Not having to travel and avoiding crowds' and 'finding bargains' more easily were also frequently named as reasons for preferring online shopping. Lastly, 'avoiding queues' and 'being able to

multitask' while shopping was considered advantages of online shopping (Statista, 2023f). In contrast, the most important reasons for preferring to make purchases in physical stores were that you can 'try on clothes', 'assess the quality of the products' and 'get the products right away'. Respondents also indicated that buying in-store can be an 'experience with friends and family' and 'supports the local economy' (Statista, 2023e).

Online shopping can contribute to lower revenue for shops with a physical store, leading to vacant shop buildings because renting the locations is not profitable for shopkeepers (Ossokina et al., 2016). At the end of 2022, the Netherlands had 12,700 vacant retail properties, which corresponds to 6% of the total number of retail properties. Interestingly, the vacancy rate was at its lowest level since 2011. However, market analyst Locatus claims that the primary cause of this declining rate is the conversion of retail properties into residential space, among other uses (Locatus, as cited in NOS Nieuws, 2023). Due to the accessibility of online shopping, consumer behaviour is expected to change to an 'experience economy': going to the city for the experience. This would mean that shopping areas should invest in attractive public spaces with good public services (Ossokina et al., 2016).

In the Netherlands, city centres are the largest and most diversified shopping locations. There are many factors that influence the attractiveness of a city centre to consumers: the physical attractiveness of shops, the diversity of products available, the quality of the service, the accessibility of the shopping location and the attitudes of the consumers regarding the overall attractiveness of the city centre environment (Parker, 1992, as referenced in Weltevreden & Van Rietbergen, 2007). Teller (2008) confirmed that the tenant mix and atmosphere significantly influence the perceived attractiveness of European shopping streets.

There has been evidence that the perceived attractiveness of a city centre can influence consumers choice between shopping online and in the city centre. Weltevreden and Van Rietbergen (2007) conducted a study in eight cities in the Netherlands that found that the perceived car accessibility of the city centre influences the extent to which car users shop online and purchase less in city centres. For non-car users, the perceived shopping attractiveness is more important, which was measured by the ambience of the city centre, the number and variety of shops, the price level, the layout of the shopping streets and the availability of pedestrian areas (Weltevreden & Van Rietbergen, 2007).

1.3. Stakeholders

An important aspect for development projects is stakeholders' engagement which helps to develop knowledge about economic, environmental, ethical, and social responsibilities (Rinaldi, 2013). Multiple stakeholders can be identified.

1.3.1. Residents and shoppers

As cities expand and face the challenges of urbanization, the concept of urban greening has emerged as an important solution for improving the quality of urban life (Georgi, 2016). This report also dives into residents' and shoppers' viewpoints and interests on urban greening initiatives in their living surrounding. Urban greening includes a wide range of interventions, with a central focus on the creation of green spaces. Understanding residents' and shoppers' perspectives is critical since they are both stakeholders and beneficiaries of these interventions, and their opinions influence the effectiveness and sustainability of urban greening implementations (Madureira et al., 2015). Previous research indicates that the number of green areas in a neighbourhood is a major positive predictor of residents' satisfaction (Bonaiuto et al., 1999; Bonaiuto et al., 2003; Bonnes, 2004) Residents can also play a significant role in creating and implementing green initiatives (Schwanitz, 2023).

According to Schroeder et al. (2006), most people believe that the advantages of street trees exceed any negative aspects. Residents prioritize aesthetics, shade, and calming effects when considering street trees for their community. Derkzen et al. (2017) discovered that providing information about the benefits of green initiatives, particularly its capacity for climate adaptation, can increase public support for adaptation initiatives. The data indicates that while residents recognized urban heat and flooding as serious future concerns, they did not necessarily understand the possibility of green initiatives as an adaptation response. While locals had a greater knowledge of green initiatives benefits that directly affect health and welfare, such as recreation and air

purification, less direct benefits were less well understood (Derkzen et al., 2017). Research by Rotherham (2010) indicates that the health of trees and planting design of trees might cause negative reactions from residents. Street trees are not always planted under proper circumstances and may not receive adequate care throughout their lives. Inadequate tree maintenance by competent specialists can lead to decreased performance and aesthetic quality, significantly impacting public perception (Rotherham, 2010).

Regarding the impact of greenery on shoppers behaviours, research has indicated that customers are more inclined to shop and spend money in shopping districts that have greenery, and that retail employees' satisfaction and productivity rise when they work in retail environments that incorporate green aspects (Browning et al., 2015; Ryan et al., 2023; Wolf, 2005). Findings by Rosenbaum et al. (2019) indicated that biophilic design components; plant life, water, animals, as well as breezes, sounds, scents, and other natural elements (Kellert & Wilson, 1993), enhance customers' neurological activity related with excitement, attention, decreased stress, engagement, interest, and relaxation, and thus explaining why shoppers tend to respond positively to greenery in shopping areas. According to a report by Cheng & Marzuki (2023) biophilic design positively improves customers' landscape preferences and encourages repeat visits and recommendations. A pleasant and appealing shopping atmosphere, enhanced by greenery, can substantially affect consumers' opinions of the retail setting.

1.3.2. Small and medium sized enterprises (SMEs)

Importance of companies

Small and medium sized companies who play a key role in developing and executing sustainable initiatives lack the necessary expertise, resources or commitment which can be found in larger companies (Moore & Manring, 2009). The municipality, which has such expertise and resources, can help SMEs towards their sustainability goals.

Short term vision

SMEs operate in competitive markets, they are compelled to cut cost to stay in business, even when these decisions cause or do not reduce damage to the environment. Therefore, SMEs mostly have a short-term vision and are focused on immediate profitability instead of long-term sustainability. According to Roarty (1997), stricter legislation protecting the environment and financial incentives can persuade companies to be more sustainable. SMEs over time do show a change in this behaviour due to both push of the government and the pull of the market due to green consumers. Despite this, only a few companies go beyond the minimum due to the costs being involved. This enforces the importance of legislation which creates a level playing field for all SMEs and makes sure that the companies can be profitable while performing well for the environment and focusing on long term profitable growth (Roarty, 1997). This levelling of the playing field is being done increasingly by not only municipalities but also stakeholders which are gradually asking SMEs to be responsible and accountable, this pressures businesses to implement sustainability measures (United Nations, 2015).

Sustainability can also be linked to Corporate Social Responsibility (CSR). Research has shown that CSR practices, especially quality stakeholder relationship management leads to improved value creation (Hammann et al., 2009). A better engagement with the society can influence the positive reputation and image of the company by customers and may lead to more profit of SMEs (Herrera Madueño, 2016). Environmental practices can also improve innovation (Chang, 2011). SMEs that actively develop practices that positively influence the environment are more likely to achieve a competitive advantage because those practices and innovations can reduce costs or lead to differentiation (López-Gamero et al., 2008).

1.3.3. NGOs

Non-governmental organizations (NGOs) are important stakeholders in improving urban development. The primary objective of NGOs is to improve the quality of life for urban residents through developments in cities (Bartosova & Podhorska, 2021). They solve urgent problems of the population by developing an appealing city which attracts businesses (Prostova, 2023). Moreover, NGOs play a crucial role in achieving community objectives. They can contribute to social and environmental improvements within their cities and when dealing with big environmental problems

working closely with NGOs is key to taking care of city forest's needs (Elton et al., 2023; Konijnendijk et al., 2021).

Increasing responsibility

Due to the emergence and activity of NGOs that improve urban areas, the governance of green and blue spaces (GBS) switched from municipalities to NGOs (Boulton et al., 2018). NGOs are now taking on more responsibilities for GBS, working together with government bodies or by using their own resources and abilities (Cheng, 2019). They also play a key role in establishing and caring for GBS, including creating, maintaining, and improving parks and gardens in cities (Connolly et al., 2013). Because NGOs are tackling issues of environmental justice connected to GBS, their role in managing and overseeing these spaces has grown which resulted in their increased involvement in the governance of GBS (Anguelovski, 2015).

1.3.4. Municipality

Municipalities have an important role in creating sustainability initiatives. They are responsible for numerous operations and resources within an area aimed at improving the well-being of the population (Levesque et al., 2017). Their role extends beyond initiating sustainable projects. They serve as important connectors in engaging different sectors of society, in particular the business community, whose participation is needed to create social and economic changes towards sustainability. The business sector which has a lot of resources and capabilities, is seen as a major player in the quest for sustainable development (Bell, 2002). Their investment and innovation capabilities make them important in the implementation and success of sustainable interventions.

Municipalities can guide small and medium-sized enterprises (SMEs) towards more sustainable practices. By facilitating access to recycling programs and waste reduction strategies, as well as making use of renewable energy sources and energy saving measures, local governments can significantly help SMEs on a path to sustainability (Lamoureux et al., 2019). This support is crucial, as SMEs often face unique challenges that require specific solutions to integrate sustainability into their operations effectively.

In addition, municipal governments can anticipate the growing demand for sustainable products and services. Through policies and initiatives, they can create an environment that prioritizes minimal environmental impact. In doing so, they help to create a more sustainable economy (Bell, 2002).

1.4. Project 'A Green Heart for Amersfoort'

The project 'A Green Heart for Amersfoort' is about green innovations for the city centre of Amersfoort. This is based on the long-term plans of the municipality of Amersfoort to green the city, one of which includes the incorporation of more green initiatives in the city centre (Gemeente Amersfoort, 2023b). The shape of Amersfoort's city centre resembles that of a heart, which inspired the title of the project, Figure 3.

The project is realized by a team of seven students from Wageningen University as part of the Academic Consultancy Training (ACT) course. Viola Bennink and Fokke de Jong from Wageningen University & Research's Science Shop serve as the project's commissioners. The commissioners have been requested by the Ondernemersvereniging Binnenstad Amersfoort (OBA), an entrepreneurs' organization consisting of shop owners in the city centre in Amersfoort, to advise them on greening solutions for the city centre. The OBA will in turn use the advice for collaboration with the municipality on projects in the city centre.

The master thesis 'Cool Retail – Towards novel, climate-resilient shopping streets' by Nick Hersbach will serve as a basis for the project. It includes information on climate-resilient innovations for Dutch shopping streets including the viewpoint of shop owners. Hersbach focused on heat stress and the effect of heavy rainfall, therefore this project will focus on biodiversity, social aspects, more stakeholders, and the limiting factors in Amersfoort (Hersbach, 2022).

The streets that we will be focusing on are the Langestraat and Krommestraat, as seen in Figure 3. The street attracts many customers from Amersfoort itself and outsiders (T. Miltenburg, personal communication, January 15, 2024). The Krommestraat is perpendicular to the Langestraat and is a narrow street, which will have different challenges and opportunities than the Langestraat,

regarding heat stress, water management, attractiveness, and biodiversity. Although narrow streets provide some shelter from the sun, solar radiation eventually reaches them and quickly heats the surfaces (Hersbach, 2022).

A short investigation revealed that the Langestraat in Amersfoort used to be a street for cars until 1981, when it was turned into a pedestrian street (De Stad Amersfoort, 2021-b). Pictures from Archief Eemland showed that the street did not have any green elements (Archief Eemland, n.d.). The Krommestraat is the oldest street in the city centre (De Stad Amersfoort, 2021-a). A picture of a part of the Krommestraat from 1930 showed no green elements either (Archief Eemland, n.d.).

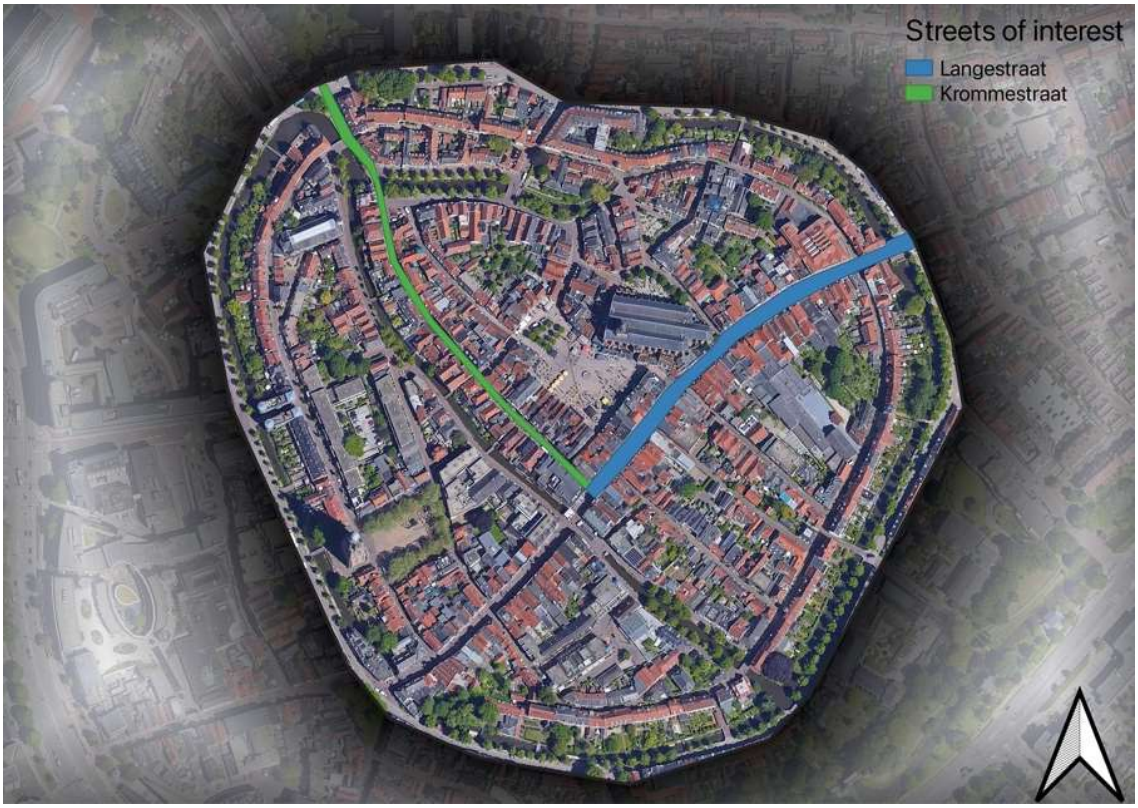


Figure 3 - The city centre of Amersfoort. The Langestraat and Krommestraat, ending at its cross-section, will be our main research area (Basemap provided by Google Maps).

The main research question we will be answering in this report is: "Which green innovations are best suited for improving water management, biodiversity, heat stress management, and attractiveness of the Langestraat and Krommestraat in Amersfoort, which are viable when considering current challenges, limiting factors in the immediate surroundings and different stakeholder viewpoints?".

To correctly answer this main question, we have decided upon these sub questions:

1. What are the current challenges affecting the Langestraat and Krommestraat and what are the limiting factors in the immediate surroundings?
2. What are important stakeholder viewpoints and interests?
3. What green innovations are available for improving water management, reducing heat stress, and increasing biodiversity and attractiveness and which have other cities implemented?
4. Is there a link between greenery and resident, visitor, and customer behaviour and well-being?

2. Methods

2.1. Sub question 1: Challenges and limiting factors

What are the current challenges affecting the Langestraat and Krommestraat and what are the limiting factors in the immediate surroundings?

To determine the current challenges Amersfoort faces, we conducted literature research and interviews.

Klimaateffectatlas

The Klimaateffectatlas was used to obtain relevant data on the climate effects on the city centre of Amersfoort. This is a website on which you can select a location and add layers to the map, for example heat stress.

Experts

Interviews, conversations, and contact were held with experts. We conversed with Theo Miltenburg (OBA member) to find out specific challenges that are not present in the literature. To obtain information on underground infrastructure we had contact with Hayko Kazancioglu and Jos de Vries. With the collected information from literature research and experts, we were able to create an inventory of challenges and limitations that Amersfoort faces.

2.1.1. Obtaining underground infrastructure information

To obtain the placement of specific infrastructure the files provided by Kadaster (can be obtained in further research via Science Shop) are loaded into the Kadaster-KLIC-viewer. Information on the Langestraat is available in file 24O0019272_1, and for the Krommestraat file 24O0019265_1 is used. The loaded file (only one at a time) shows all underground infrastructure, to maintain a good overview, single provider infrastructure can be selected in the drop-down menu, Figure 4.

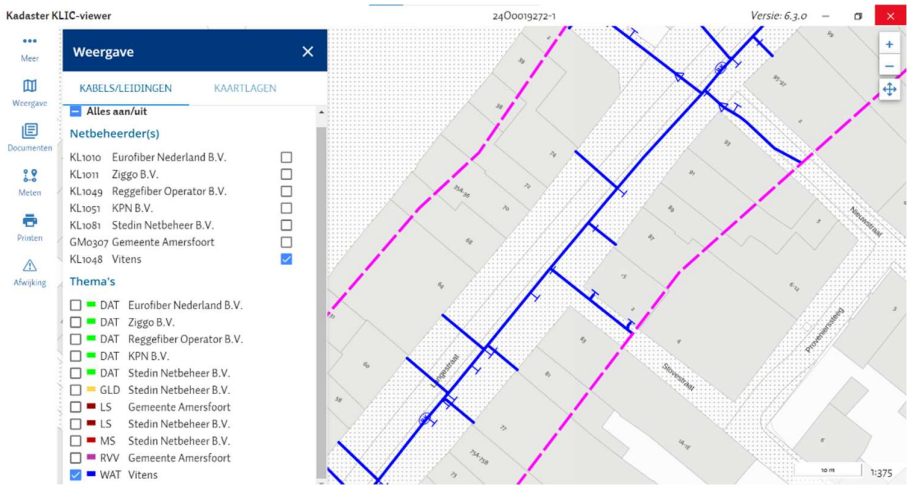


Figure 4 - The drop-down menu 'weergave' in Kadaster KLIC-viewer. Only drink water infrastructure (Vitens) is selected.

The files obtained by the municipality have been loaded and processed in QGIS. QGIS is a Geographic Information System application that is free and open source (FOS) (QGIS, n.d.). The steps taken to load and process the data into QGIS to create a visible map, are the following:

1. Open a new project in QGIS.
2. Open data source manager. Go to 'Vector'. From here select the files received by the municipality. Load both files into the project.
3. Use the 'Select by value' tool. To select the different follow types of cables and pipelines, select 'contains' and enter the following terms into 'id': 'GasOlie', 'Elektriciteit', 'Water','Riool', and 'Data'. After selecting one of the terms, right-click on the layer in the layer panel and select 'create layer of selected values'.
4. Adjust the symbology to create a distinguishable set of layers.

Further steps used to create maps in QGIS are described in the flowchart of Figure 7.

2.1.2. Biodiversity and soil

In the literature research, multiple sources were used to get information on the biodiversity and the type of soil of Amersfoort. The species that were written down were found in governmental reports from either the municipality of Amersfoort or the province of Utrecht. We specifically took the information from the document Stand van de Natuur in Amersfoort (Beers et al., 2019) and selected the species that were shown to be present during 2011-2018 in the four squares covering the city centre. The soil profile of Amersfoort was found on Bodemloket. The main governmental report that was used for the legislation of biodiversity was the HIOR.

To find out what species are important in the inner city, we visited a Groenvisie meeting in Het Groene Huis. During this meeting, we talked to the city ecologists of Amersfoort who are working on a plan to improve the biodiversity of Amersfoort. As part of this, they made a list of species that are indicative of a healthy biodiversity, the "33 gidssoorten". Of these, we only took the ones that were important in the city environment.

2.1.3. Regulations for monumental buildings

To determine the regulations that need to be considered, we looked for an overview of the types of monumental buildings that were present in Amersfoort on the website of the municipality (Amersfoort.nl) and at the website of Amersfoort in beeld.

We searched for the specific regulations about different types of monumental buildings in the Erfgoedwet and the new Omgevingswet. We also searched for regulations from the municipality of Amersfoort for the "Gemeentelijke monumenten" (municipal monuments) and "monumentale stadsgezichten" (monumental city views).

Lastly, we contacted the municipality of Amersfoort to ask them about the possibilities and limitations for greening monumental buildings and city views.

2.2. Sub question 2: Stakeholders

What are important stakeholder viewpoints and interests?

Understanding residents' and shoppers' perspectives is critical since they are both stakeholders and beneficiaries of the interventions in this report, and their opinions influence the effectiveness and sustainability of the greening implementations in the city centre.

We used a combined approach of literature research and information gathered from qualitative interviews to get the viewpoints and interest of stakeholders. This includes a scientific literature review, website analysis / review, and interviews with stakeholders.

Table 1 - Number of people interviewed.

Stakeholder / Responses	Contacted	Interviews
Residents	7	3
Shoppers	3	2
OBA	32	5
NGOs	7	1
Municipality	3	0

2.2.1. Residents and shoppers

Facilitation session residents and shoppers Amersfoort

On February 1st, a session was organised in Amersfoort to gain insights on the views of residents (and shoppers) of Amersfoort on greening, the areas of interest were the Langestraat and de Kamp. The session was organized and facilitated by students of the course Facilitating Interactive Processes. 7 residents participated in the session, and it took place in café Hemels in the city centre of Amersfoort. The aim of the facilitating session was *''receiving ideas and perspective of the shopping public/citizens on how regreening could be included in the redevelopment of the city centre of Amersfoort''*. The participants were asked about their thoughts regarding the topic and shared

their own stories. The session provided a general idea of what the residents of the city found important and what they would like to see in the city centre in regard to green initiatives.

Residents

After the facilitation session in Amersfoort, a list of the participants was acquired for individual interviews. The participants of the facilitation session agreed that their email could get used to reach out for further contact. To further study the residents of Amersfoort qualitative research has been used, consisting of three semi-structured interviews. This amount was selected based on the provided information on qualitative research from WUR (Wageningen University & Research). The two first interviews took place in the afternoon of February 19th in Amersfoort, at a resident's home and one in café Hemels in the city centre of Amersfoort. The third interview was done online through the application Teams. The residents, 2 females and one male, had an age ranging from 65 to 77 years old. The topics discussed were opinion on greening, reasons for greening, climate (change), biodiversity, challenges, and possible negative effects of greening. The first two interviews took around 50 minutes and the third around 30 minutes. The interviews were recorded, transcribed and open-coded to analyse the answers.

Shoppers

Convenience sampling was used to contact 3 shoppers of Amersfoort. Eventually 2 shoppers of the city centre of Amersfoort were interviewed. The participants were 23- and 27-year-old females. One living in Amersfoort (not in the city centre) and one living in Utrecht. The first interview took place on the 17th of February and took about 45 minutes. The second interview was done through e-mail. This automatically made the questions to this interview structured. The answers of the interviewees were written out and send back by mail. Therefore, transcribing the interviews was not necessary. The text was coded on different subjects, including shopping preferences, suggestions for improving the city centre of Amersfoort, experiences in the city centre of Amersfoort, greening initiatives, and biodiversity.

Interview citizen initiative expert

One interview was held with an expert on citizen initiatives in Amersfoort. This expert lives in Amersfoort and works as a volunteer with and for many initiatives in the city. This interview helped us with gaining insight into current citizen initiatives in Amersfoort as well as the challenges, limitations and pitfalls that arise whilst initiating and implementing the initiatives. The qualitative interview consisted of an open structure. Two people of the project group conducted this interview. Teams' application was used, and the interview lasted an hour.

2.2.2. OBA, NGOs and Municipality

Scientific Literature Review

We gathered information about greening, sustainability and relationships of the OBA, NGOs and the Municipality by doing an extensive scientific literature study. For this we used databases such as Scopus, ScienceDirect and google scholar to gather information with the use of keywords related to the subjects. Also, the thesis of Nick Hersbach was used to gather information.

Website Analysis

The official website of the OBA, NGOs and the Municipality where thoroughly analysed to gather contract information, details about previous, current and future projects, and viewpoints.

Interviews with OBA

Interviews with the oba were done. To find possible interviewees who were willing to partake in the interviews multiple steps had been taken: First an interview was made according to the MOMs test which specializes in asking the right questions and information made available by the WUR on the Brightspace of the ACT course of 2024. Then members of the OBA were identified by using their website and doing research with google map. The research with google maps was done by listing all the SMEs on the Langestraat and Krommestraat. Then their contact information was retrieved from the website of the OBA and the SMEs their own websites. This contact information was a mix of personal emails, general contact emails and customer question emails. Afterwards an email was sent to each member asking for an interview, totalling 32 emails being sent, 1 to each member, telling them about the project and permission for an interview. If the member accepted an online text-based interview was sent via the mail which they could fill in and sent back. Unfortunately, due to

time limitation in-person or online interviews were not possible. All interview questions and answers were in Dutch.

Interviews with NGOs

To gather more information and insights of the NGOs, an interview was done. To find possible interviewees who were willing to partake in the interviews multiple steps had been taken: as with the OBA, firstly an interview was made according to the MOMs test (which specializes in asking the right questions and information made available by the WUR on the Brightspace of the act course of 2024). Then the contact information of the NGOs was gathered on the website, after this was done, they were contacted via email with an explanation of the project and asking if they wanted to participate in an interview. Unfortunately, no response had been received.

Then we identified volunteers who participated in projects of one of the NGO which we found the most important with a combination of their website, LinkedIn, and news articles. From this list 9 volunteers were contacted, 3 volunteers responded and 1 volunteer agreed to an interview. For a quicker response, the interview was done text based via email. The interview questions and answers were in Dutch. The answers to the questions were then coded to identify the positive, negative, and neutral opinion of the members relating multiple factors: General opinion, heat stress, water nuisance, crowdedness, greening, and biodiversity.

2.3. Sub question 3: Green innovations

What green innovations are available for improving water management, reducing heat stress, and increasing biodiversity and attractiveness and which have other cities implemented?

To determine which innovations are available, we conducted literature research, interviewed experts, and visited other cities which have implemented greening solutions. We made an inventory of the innovations we found.

For the literature research, we will search for innovations related to water management, heat stress, biodiversity, and attractiveness on databases such as Google Scholar, Scopus and Web of Science.

There were two interviews conducted. The first one was with Petra van Duivenvoorde from the municipality of Alkmaar and the second one with Joris Voeten an expert on city innovations, especially on trees.

Interview 1: Three members of our team interviewed Petra van Duivenvoorde from the municipality of Alkmaar about their greening project in de Laat and their smaller streets. The interview was about the conditions there were for the implementation, what benefits they experienced and what drawbacks there were relating to their innovations. We tried to contact the municipality of Utrecht and the municipality of Amsterdam multiple times, but these municipalities did not come back to us. Therefore, on the day we interviewed Petra van Duivenvoorde in Alkmaar we also visited Amsterdam. In Amsterdam and Alkmaar, we made pictures of innovations seen in these cities. In Amsterdam we went to Kattenburgerstraat, Bomenplein, Oudezijdsvoorburgwal Zuid, entrance Hortus Botanicus, Rijnstraat, Rijksmuseum Amsterdam, Johannes Vermeerstraat as per recommendation of a colleague of Viola Bennink. In Alkmaar we took pictures of the innovations in de Laat and a couple of side streets like the Boterstraat and the Hoogstraat.

Interview 2: Three members of our team joined a meeting with Viola Bennink and Joris Voeten to talk about innovations suitable in the Langestraat and Krommestraat, which focused especially on trees. Notes were taken during this meeting, and J. Voeten send the details to his presentation about this topic via e-mail.

To research the depth of rooting and the time certain plant species are green or flowering Google search and Google scholar was used. This information was put in a table, the information of the depth was also used to create an overview of a map showing what plants can be placed in which spot on a small scale. To determine the plant attributes best suited for Amersfoort, plants were selected that together create an attractive image while keeping in mind biodiversity and the soil type of Amersfoort.

2.4. Sub question 4: Effect on people

Is there a link between greenery and resident, visitor and customer behaviour and well-being?

Research question 4 was answered by conducting a comprehensive literature study and consolidating the findings. Multiple people were contacted and asked for recommendations on literature, including Dr. Sjerp de Vries (Senior researcher at Wageningen University & Research), Dr. Lenneke Vaandrager (Associate Professor of Health & Society at Wageningen University & Research), Dr. Wendy Tan (Professor of Land Use Planning at Wageningen University & Research). Some of the persons contacted stated that this was not within their area of expertise. The initial goal was to do an interview, however no expert agreed to be interviewed.

2.5. Main question: Suitable innovations

Which green innovations are best suited for improving water management, biodiversity, heat stress management and attractiveness of the Langestraat and Krommestraat in Amersfoort, which are viable when considering current challenges, limiting factors in the immediate surroundings and different stakeholder viewpoints?

To ensure that the green innovations align with the current challenges, limiting factors, and stakeholder viewpoints and interests, we use the inventories created for sub-questions 1 and 2, and compared these insights to the inventory of green innovations created for sub-question 3.

2.5.1. Green depth availability cross-section

To visualize what underground space is available for trees, a cross-section of a part of the langestraat was made. These cross-sections contain accurate underground infrastructure depth and placement. First accurate underground infrastructure placement was needed. For this a Kadaster KLIC-melding of the Langestraat was used in Kadaster-KLIC-Viewer. Measurements on specific infrastructure placement relative to street profile was done via the measurement tool in Kadaster-KLIC-viewer.

2.5.2. Measuring specific infrastructure placement

In kadaster-KLIC-Viewer the drop-down menu contains the option 'meten,' which is the measurement tool in the application. Selecting two specific points the application will provide an exact distance between the points. With this total street profile distance and distance from infrastructure relative to the street profile can be calculated (Figure 5).

To obtain accurate infrastructure depth, the "principe profiel" attached to the KLIC-melding was used. In this file a standard profile of the Langestraat can be seen, containing 'normal' infrastructure depth.

For accurate sewage system depth and placement, the files obtained from the municipality were used (folder 'Sewage data'). In this file the Ground level and B.O.B (Binnen Onderkant Buis) were available. B.O.B. is the depth of the sewage system compared to N.A.P (Normaal Amsterdams Peil) (*B.O.B - Hunze En Aa's*, n.d.). Ground level is the height of the ground compared to N.A.P. With this the exact depth of the sewage system can be calculated (Figure 6).

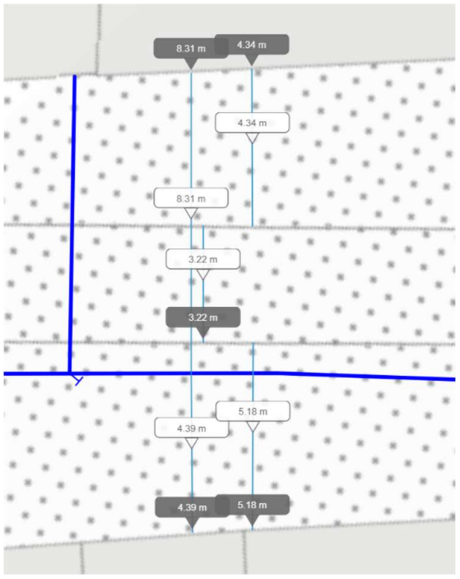


Figure 5 - Example of measurements on drink water infrastructure in the Langestraat (Vitens, 150 GIJ, in figure represented as a blue line) relative to the street profile, measurements on road position relative to street profile and measurements on street width. Using Kadaster-KLIC-viewer

The size of specific underground infrastructure can be found by clicking on the line representation in Kadaster KLIC-viewer and looking at 'diameter.' When diameter did not provide information on the size of the infrastructure, a safe estimation of 25cm by 25cm was used.

After this data was obtained for a specific place in the Langestraat Appendix A. The results were represented through a figure made in Canva, a graphic design software. The distances in meters were converted into exact pixel distances, for example 1 meter = 1000 pixels, Appendix B. Through this the relative placement of the infrastructure could be calculated and visualised. The root space was calculated from the results gained from the QGIS map buffer space.

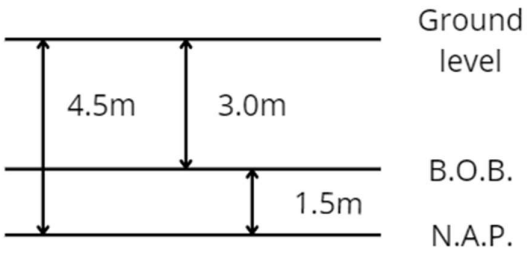


Figure 6 - An example of a sewage depth placement measurement: A B.O.B of 1.5m and a ground level of 4.5m would mean 4.5 - 1.5 = A depth for B.O.B of 3 m is found. To find the depth of the top of the sewage system the diameter of the system needs to be added.

2.5.3. Available space for planting trees maps

In the following flowchart the steps for preparing the maps of the Langestraat and Krommestraat is presented. All data used for input and output is processed in QGIS. QGIS is a Geographic Information System application that is free and open source (FOS) (QGIS, n.d.). In the legend the symbology of all components can be seen. A description of all the tools written in bold can be found in Appendix C.

The buffers that were created are constructed based on the distance that a tree can be planted from a certain cable or pipeline. The cables and pipelines that are accounted for here are included on the map constructed for research question 1. This distance is determined by measuring the stem of a tree and multiplying this by 10 (J. Voeten, Personal Communication, February 26, 2024). This distance is then used as an input for the buffer tool in the flowchart.

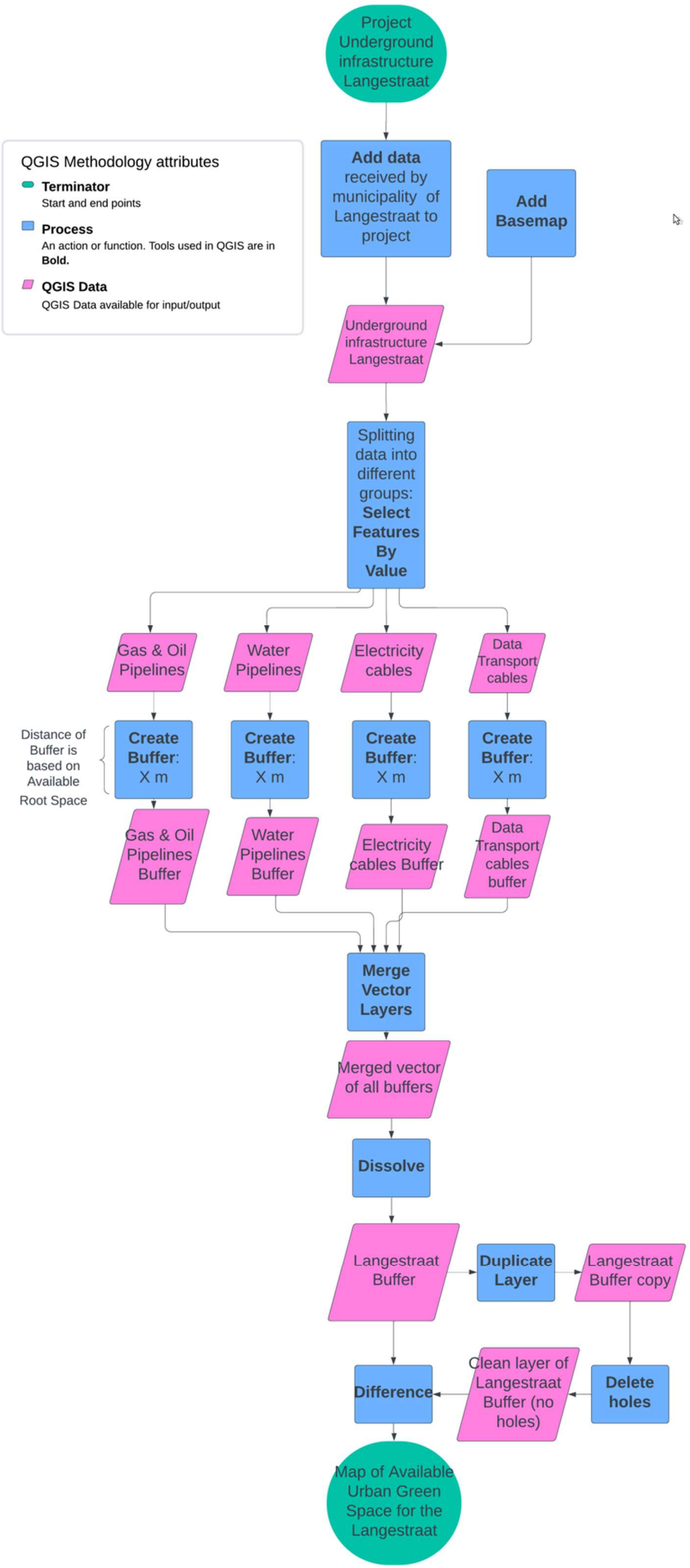


Figure 7 - Flowchart representing the overall workflow to create the maps with available space for tree planting.

3. Results

3.1. Sub question 1: Challenges and limiting factors

3.1.1. Challenges

According to Dennis Stille from the city marketing Amersfoort, the effects of the growth of online shopping have been visible in the city since 2019. People now come to the city centre for the experience rather than the convenience. "We also respond to that. We hope to make the city centre more of a 'place to be' instead of a 'place to buy'." (Sille, as cited in Groot, 2023). To make Amersfoort a place to be, there are challenges that need to be addressed.

Amersfoort has already felt the effect of climate change in the city centre. Heat stress and local flooding due to heavy rainfall already is seen as a problem in the city centre of Amersfoort (T. Miltenburg, personal communication, January 15, 2024). Due to climate change this is expected to increase over time.

Maps of heat stress

In Figure 8, the heat stress Amersfoort would endure in 2050, according to KNMI climate scenario W(H) (KNMI, 2015), is compared to the current heat stress. The KNMI released 4 climate scenarios for the Netherlands in 2014 (KNMI, 2015). The scenario used for the maps predicts the largest change. This change would mean an increase in days with a temperature above 30 degrees Celsius, which would mean more heat stress. Thus, the Langestraat and Krommestraat will have extreme heat stress in the future.

Figure 8 - Current heat stress of the city centre compared to heat stress in 2050.

Maps flooding Amersfoort

In Figure 9, the depth of rainwater puddles forming in the city centre after an extreme rain event of 140mm in two hours is shown. This rain event is regarded as a stress test event and will occur only once every 250 years. The Krommestraat over its entirety will endure rainwater puddles with a depth of 5-15cm, with a hotspot of over 30cm. The Langestraat will endure two hotspots, with a depth of 5-20cm.

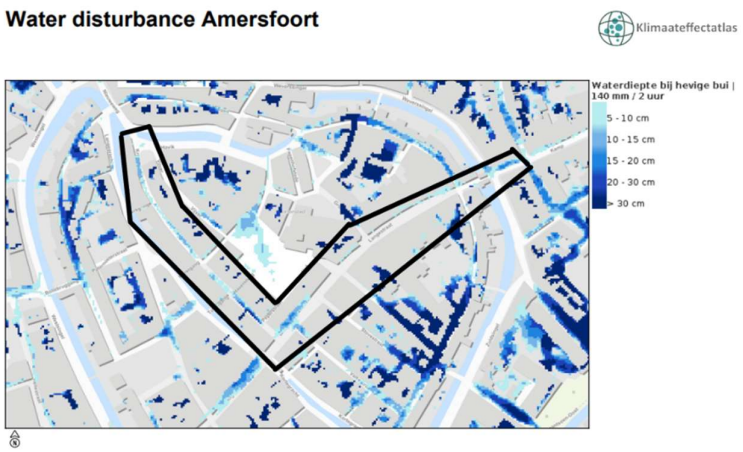


Figure 9 - Depth of rainwater after extreme rainfall (140 mm) after 2 hours.

Biodiversity in Amersfoort

Species

From the report Stand van de Natuur in Amersfoort (Beers et al., 2019) we learned that there are quite some animal species and herbs present around the city core in which the Langestraat and Krommestraat are located. Appendix D shows the list of species that were present in the period between 2011 and 2018. However, many species will not be present in the shopping streets specifically.

The animal and plant species that the municipality wants to find in the city area are shown in Table 2. For the Langestraat and Krommestraat, we should choose solutions that attract and sustain these species. More information can be found in the future in the document *Deelomgevingsprogramma biodiversiteit*, but the municipality is still working out more information on what these species need (L. de Haan, personal communication, February 26, 2024).

Table 2 - List of important indicator species (gidssoorten) in the city of Amersfoort at the level of the street and individual buildings (L. de Haan, personal communication, February 26, 2024).

Street level	**Building level**
Huismus	Huismus
Kleine watersalamander	Kleine watersalamander
Wilde bijen	Wilde bijen
Muurplanten	Muurplanten
Zwarte roodstaart	Zwarte roodstaart
Egel	Gierzwaluw
Gewone dwergvleermuis	
Zwartkop	

Trees

In the Netherlands there are lists set up to create an understanding on the effect certain tree species have on the biodiversity of the Netherlands. There are three categories, the green list includes native and exotic trees that positively contribute to biodiversity. The black list includes invasive exotic species which should not be planted in the Netherlands. The rest list includes all the tree species that are not on the green or the black list. In Amersfoort they have paid attention to the green and black list, this can be seen in the fact that 81% of the trees are from the green list, 15% from the rest list and 3% from the black list. The 5 species that are most common are, in order, the zomereik, zwarte els, es, beuk and ruwe beuk. In Figure 10, the species are shown with the number of trees in Amersfoort (Natuur & Milieu, 2023). The use of the black and green list has been a topic of discussion within ecologists. It is a guideline that can be used, but not leading, the most important thing is that the trees are not invasive (J. Spijker, personal communication, February 27, 2024). That is why underneath Sub question 3 – Green innovations in Amersfoort the "Bomentabel"

was used of Hiemstra (2011). An updated version of which will be published May 2024 (J. Spijker, personal communication, February 27, 2024).

Meest voorkomende soorten	Aantal bomen	Percentage	Lijst	Nederlandse naam
Quercus robur	18.597	36%	groen	Zomereik
Alnus glutinosa	7.536	15%	groen	Zwarte els
Fraxinus excelsior	4.672	9%	groen	Es
Fagus sylvatica	4.441	9%	groen	Beuk
Betula pendula	3.321	6%	groen	Ruwe berk

Figure 10 - Table including the most common trees in Amersfoort and the amount (Natuur & Milieu, 2023).

Trees in Amersfoort

There is currently 5% - 10% trees per neighbourhood in which the Langestraat and Krommestraat are located, Figure 11. This neighbourhood consists of the squares, including Hof, and other areas of the city centre. In the Langestraat and Krommestraat there were no trees. This shows that although Amersfoort is keen on planting trees that are beneficial to the biodiversity, this is not reflected in our study area.

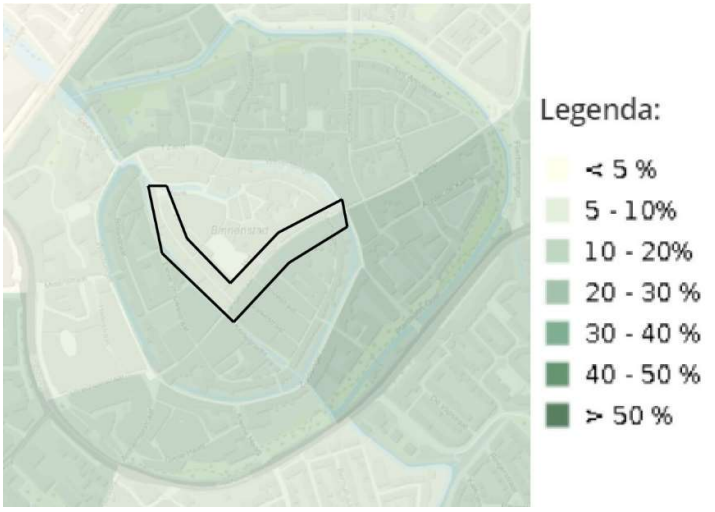


Figure 11 - Percentage of trees in the neighbourhoods of Amersfoort city centre (Cobra Groeninzichten, 2021, as referenced in Klimaateffectatlas, n.d.).

Green in Amersfoort

As can be seen in Figure 12, the percentage of small green in the neighbourhood of the Langestraat and Krommestraat is less than 10%. Compared to the rest of the city centre it has the least green. Small green in this case is green such as shrubs and grass.

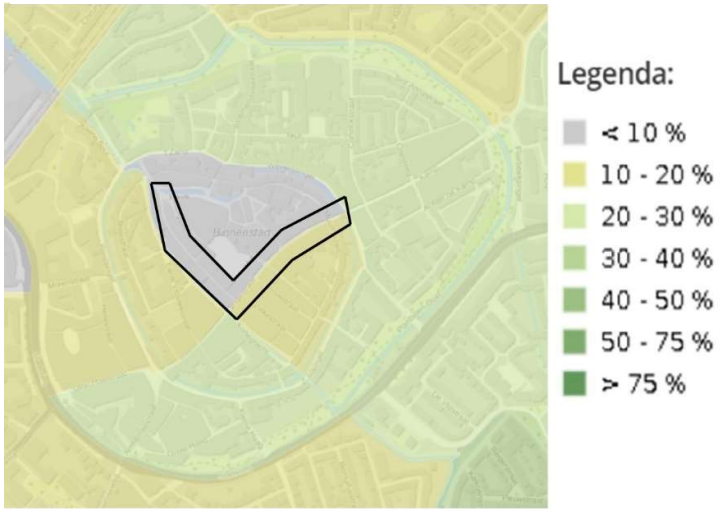


Figure 12 -Percentage of small green in the neighbourhoods of Amersfoort city centre (Cobra Groeninzichten, 2021, as referenced in Klimaateffectatlas, n.d.).

Grey in Amersfoort

The neighbourhood the Langestraat and Krommestraat are in is shown to have 60 % - 70% grey in the area, Figure 13.

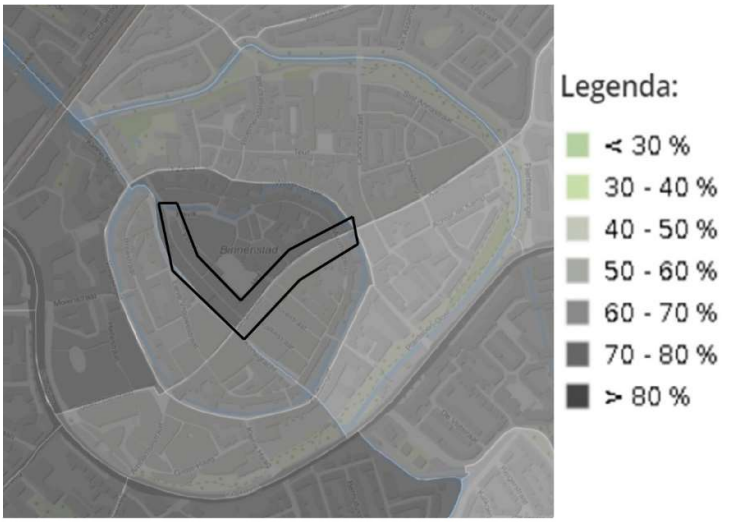


Figure 13 - Percentage of inorganic matter, such as stones or bare soil in the neighbourhoods of Amersfoort city centre (Cobra Groeninzichten, 2021, as referenced in Klimaateffectatlas, n.d.).

3.1.2. Limiting factors

When greening a shopping street many aspects need to be considered. For implementing innovations there are several limiting factors, both above and below the ground surface level.

HIOR

The "Handboek Inrichting Openbare Ruimte", in short, the HIOR, is a manual for the municipality of Amersfoort. There are rules described here, such as: there will only be ecological bulbs planted by the municipality. In here it is possible to check whether the plans made are feasible by the municipality's standard. And what needs to be taken into consideration.

Above ground Limitations

Limitations for innovations found on above street, stem from the functionality the shopping streets have now. The shopping streets are used by different modes of traffic. Pedestrians, cyclists, vehicles for loading and unloading, emergency vehicles and garbage trucks often visit these streets. The above ground infrastructure has been designed to fit the types of usage the different modes of traffic have.

Loading and unloading

One of the limiting factors of a shopping street is the need for loading and unloading of goods for the shops within the city centre and on the shopping streets. This activity causes hindrance within the shopping street, such as sound pollution and air pollution. The city of Amersfoort therefore chose to make parts of the city centre "autoluw" (car-free) and executes this since Januari 2021, meaning that those parts are only accessible for cyclists and pedestrians. Only during certain hours, for example between 7:00 and 11:00 in the morning, vehicles are allowed to enter the specific regions. The specific regions are shown in Figure 14 (Gemeente Amersfoort, n.d.-f).

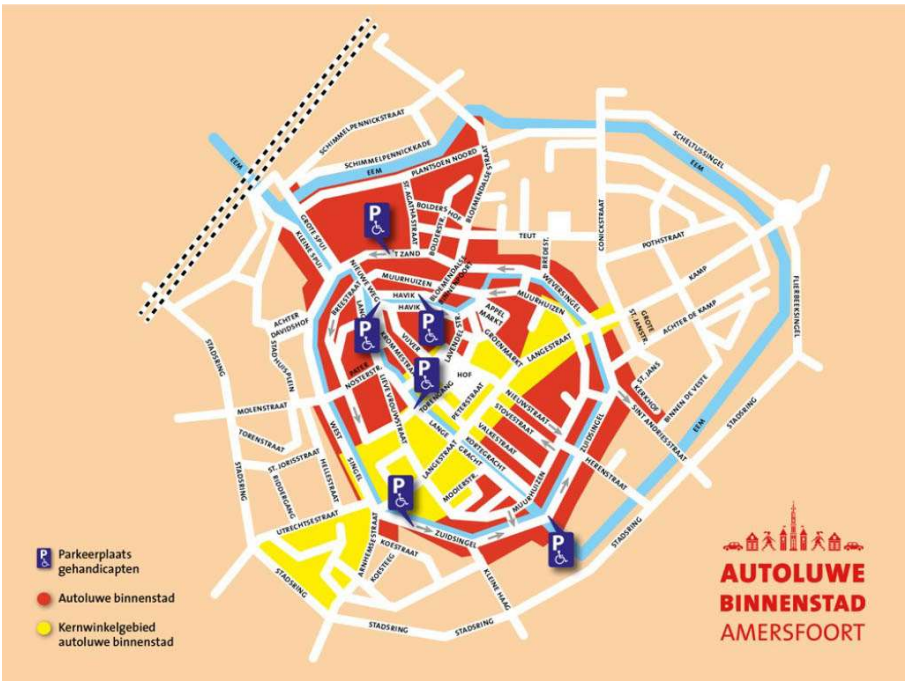


Figure 14 - Map of Amersfoort, showing in red autoluwe part of City centre, and in yellow the core shopping area of the autoluwe city centre, which encompasses the Langestraat and part of the Krommestraat.

To fight these problems even more the city of Amersfoort also agreed on making the city centre zero emission by 2025 through Zero Emissie Stadslogistiek (ZES) (Gemeente Amersfoort, n.d.-g). In which is stated that the "kernwinkelgebied" (main shopping area), Figure 15, must be emission free by Januari 2025 and the "autoluwe binnenstad" (care-free city centre) must be emission free by Januari 2027.

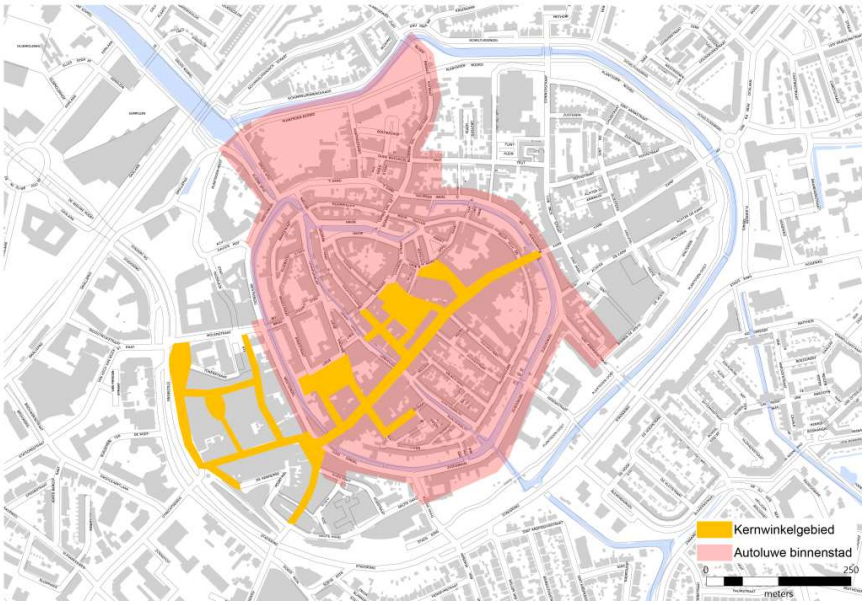


Figure 15 - Map of Amersfoort showing the "kernwinkelgebied" in yellow and the autoluwe binnenstad in red.

However, the need for delivery of goods is currently still a necessity for the city centre of Amersfoort. To be able to provide a shopping street with goods in the current situation. A shopping street should have enough space for a delivery vehicle to drive in and out of the shopping street, as well as enough space for parking. The pavement should be able to handle to load stress from the vehicles delivering the goods.

When considering innovations for greening the shopping streets, the usage for loading and unloading need to be taken into consideration. An adaptation on the innovations or adaptation on the current usage is necessary.

Emergency vehicles and garbage trucks

To have enough room in the shopping streets for emergency vehicles and garbage trucks a minimum of 3.5 meters free space is necessary (*Handreiking Bereikbaarheid Hulpdiensten*, n.d.). This has to be considered when implementing innovations.

Pedestrians and cyclists

Besides delivery vehicles the streets are also used by cyclists, Amersfoort provides these cyclists with Bicycle parking spaces in the Langestraat, Figure 16. However, bicycle parking takes up considerable space in the Langestraat.

Figure 16 - Bicycle parking space in the Langestraat.

The final mode of traffic in the shopping streets are pedestrians. The municipality of Amersfoort want to give the pedestrians more space (Gemeente Amersfoort, n.d.-f). During the day, all space within the shopping street is available for pedestrians to walk.

Light system

Currently, the lighting system on the langestraat consists of light poles alternating on both sides of the street, Figure 17. Baskets with flowers are attached to these light poles. However, these light poles will be removed and replaced by Façade lighting in the entire Langestraat. The plan made by the municipality of Amersfoort states that these light poles will be removed by 2025 (Gemeente Amersfoort, n.d.-d). The new façade lighting system will impose different problems. Façade lighting cannot be blocked by green innovations, such as façade climbing plants. Thus, considerable space around this lighting system is needed to make sure the system is effective and not blocked.

Figure 17 - Bicycle parking space in the Langestraat.

Underground limitations

Plants, trees, and other vegetation root into the ground with a variety of depth. To grow vegetation needs enough room. If vegetation is not given enough room to grow their roots, it can damage underground infrastructure. Thus, it is especially important to know the exact locations and placement of the underground infrastructure. The underground infrastructure of parts of the Langestraat and Krommestraat can be seen in the Figure 18a & b.

Figure 18 a & b - A zoomed in map of the underground infrastructure of the Langestraat and Krommestraat. The variety of infrastructure types can be seen, indicating the limitations to planting green innovations.

The underground infrastructure of the Langestraat and Krommestraat is very complex but placed in ordered fashion. Low voltage cables are grouped together on both sides of the street, as well as data cables.

The maps in Figure 18, do not represent the occurring depth of the systems. For this the "principeprofiel" or standard profile (Figure 19) can be used. The number of cables with depths not conform to the standard profile is limited. For the Langestraat 7 cables deviate from the standard profile, but these cables' depths are given in separate profiles, Figure 20. In the Krommestraat 5 cables deviate from the standard profile.

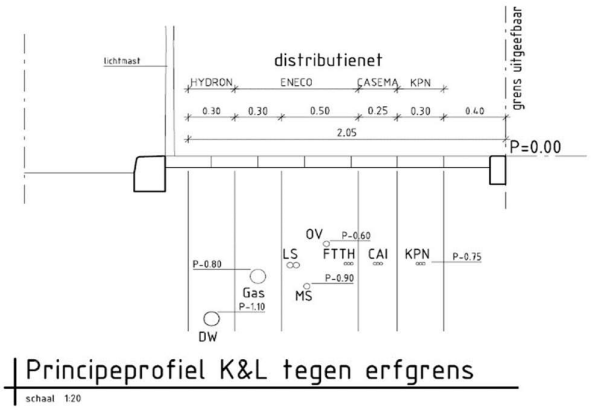


Figure 19 - Standard profile, "principeprofiel", of the underground infrastructure in the shopping streets.

However, cable placement can differ from reality, as well as the existence of undocumented or unused infrastructure. This could pose a problem when implementing the innovations into the street. Undocumented infrastructure cannot be removed immediately, because of potential dangers. The infrastructure could still be in use. To find out exact placement of infrastructure test slots are used, Figure 21.

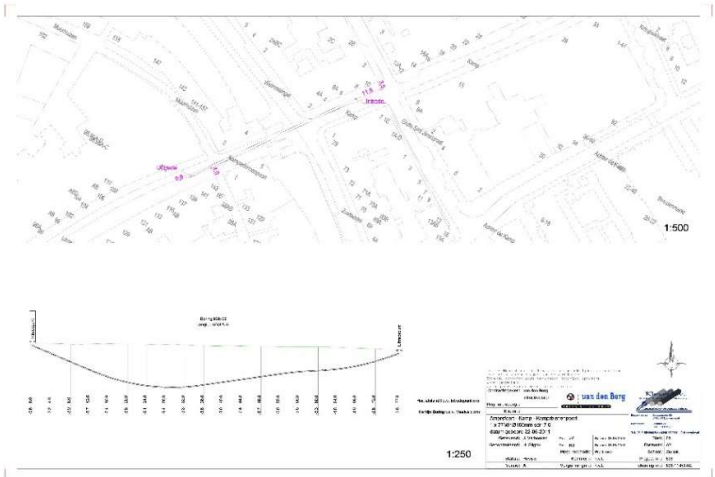


Figure 20 - Profile of a cable placed in the Langestraat.

Figure 21 - Test slot in de Kamp showing underground infrastructure.

3.1.3. Soil

The city centre of Amersfoort is located on "dekzandgebied". The geomorphy of the Langestraat and Krommestraat is "dalvormige laagte" and "dekzand rug". In Figure 22 a soil sample in the city centre is shown. In this Figure it is clear that the first layer of the soil consists of sand of the middle category, and only at around 12 meters deep from mowing level, it has 6 meters clay. After this layer there are layers of sand and clay again. The sand categorized as sand of the middle category is 150-300 mu (DINOloket, n.d.). This means that the sand is in between coarse and fine sand (Buijens - van Rossum, 2023). Sand has certain properties that differ from other soil types. Sand is more permeable than soil types like clay. The water which falls will easily run off. This causes plants to reach their wilting point earlier. Another effect of this run off is that there are less nutrients in the soil (Huang & Hartemink, 2020). This means you would have to have plants that can withstand dry seasons.

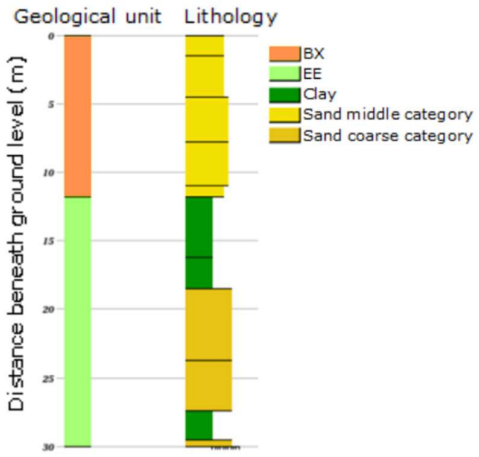


Figure 22 – A soil sample of the city centre. BX = Formation of Boxtel, EE = Eem Formation (DINOloket, n.d.).

3.1.4. Groundwater

Currently the average of the lowest groundwater level is between 1.5 m and 2 m, the average lowest groundwater level after a dry summer is less than 2 m. The average highest groundwater level in the Langestraat and Krommestraat varies in the street, it ranges between 1 m and 2 m, Figure 23 (Nationaal Water Model, 2016, as referenced in Klimaateffectatlas, n.d.).

In 2050 some ground water levels will change in Amersfoort, according to KNMI climate scenario W(H) (KNMI, 2015). The average lowest groundwater level in normal circumstances or after a dry city do not change. The average highest groundwater level will have a slight increase of 0,1 m to 0,25 m. And the chance of the ground water causing any disturbances is very small (Nationaal Water Model, 2016, as referenced in Klimaateffectatlas, n.d.).

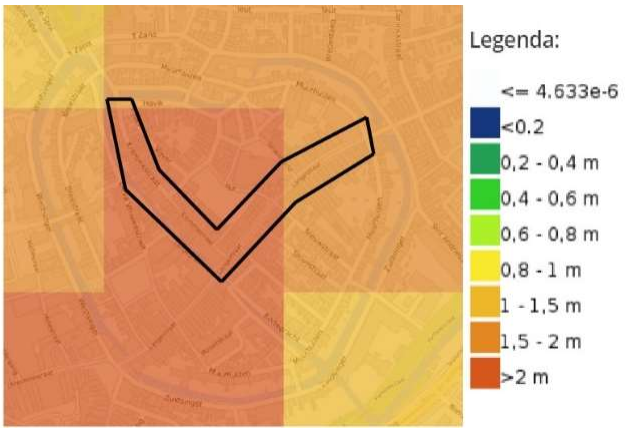


Figure 23 - Current average highest water level (Nationaal Water Model, 2016, as referenced in Klimaateffectatlas, n.d.).

3.1.5. Heritage

Figure 24 – monumental buildings in the city centre of Amersfoort (Amersfoort in beeld, n.d.).

The map above (Figure 24) shows the types of monumental buildings in the city centre, and it is clear that there are many national (red) and municipal (blue) monuments in the Krommestraat and Langestraat, as well as many view determining buildings (yellow) (Amersfoort in beeld, n.d.).

In the Erfgoedwet and Omgevingswet we could not find relevant information about the limitations for altering something about monumental buildings. We did find a regulation from the municipality of Amersfoort, the Erfgoedverordening Amersfoort 2010, which states in Article 6(1) that it is forbidden to damage, alter or use municipal monuments in any way that would deface or threaten it, and in Article 12(1) that it is forbidden to damage, alter or use real estate located in a municipal city view in any way that would deface or threaten the view (Erfgoedverordening Amersfoort, 2010). We were unable to find a clear description of what would constitute such damage.

Article 6(1): "*Het is verboden een gemeentelijk monument te beschadigen, te vernielen, af te breken, te verstoren, te verplaatsen, in enig opzicht te wijzigen, te herstellen, te gebruiken of te laten gebruiken op een wijze waardoor het wordt ontsierd of in gevaar gebracht.*"

Article 12(1): "*Het is verboden onroerende zaken die gelegen zijn in een gemeentelijk stadsgezicht te beschadigen of te vernielen, af te breken, te verstoren, te verplaatsen, in enig opzicht te wijzigen, te herstellen of te laten gebruiken op een wijze waardoor het stadsgezicht wordt ontsierd of in gevaar gebracht.*"

The municipality wrote back to us with the answer that alterations of monumental buildings are possible, so long as the historical value and character of the building and the view are maintained. What this means, differs per building, and is determined by an independent heritage committee. Most alterations will require a permit, based on the Omgevingswet (S. Hovens, personal communication, February 21, 2024). With a permit and a 'zelfbeheerovereenkomst' you can plant your own façade garden (Gemeente Amersfoort, n.d.-c).

Also important is that for disturbance of the soil deeper than 30cm it is required to consult the municipal archaeologist about the nature of the research that must be conducted beforehand because of the high archaeological value of the city centre (Gemeente Amersfoort, 2014).

3.2. Sub question 2: Stakeholders

In the table below (Table 3) the different stakeholders of this project are presented, and their viewpoints regarding the greening of the city centre of Amersfoort are shown using the most important or most mentioned aspects during this research. Every stakeholder will be shortly discussed in this chapter. More on the different stakeholders can be found in Appendix E regarding the residents and shoppers, and Appendix F and G regarding the OBA and NGO's.

Table 3 Stakeholders viewpoints regarding greening

	OBA	Municipality	NGO's	Residents	Shoppers
Finds Greening important	*Neutral*	*Positive*	*Positive*	*Positive*	*Positive*
Current attractiveness	*Positive*	*Positive*	*Positive*	*Neutral*	*Positive*
Finds biodiversity important	*Neutral*	*Positive*	*Positive*	*Positive*	*Positive*
Finds social cohesion important	*N/A*	*N/A*	*N/A*	*Positive*	*N/A*
Current atmosphere	*Positive*	*Positive*	*Positive*	*Negative*	*Positive*
Finds climate change important	*Positive*	*Positive*	*Positive*	*Positive*	*Positive*
Current Stoning	*Negative*	*Negative*	*Negative*	*Negative*	*Negative*
Current bike regulation	*Negative*	*N/A*	*Negative*	*Negative*	*Neutral*

Finds "aspect" important: Relates to the opinion the stakeholders have about the aspect, Positive: The stakeholder finds the aspect important, Neutral: the stakeholder finds the aspect neither important nor not important, Negative: The stakeholder finds the aspect not important.

Current "aspect": Relates to the opinion the stakeholder has about the aspect in the Langestraat and Krommestraat in its current state. Positive: The stakeholder has a positive opinion about this aspect in the focus area, Neutral: The stakeholder has neither a positive nor negative opinion about this aspect in the focus area, negative: The stakeholder has a negative opinion about this aspect in the focus area.

3.2.1. Residents session Amersfoort and interviews

The following list gives includes a brief summary of the most important insights from the Facilitation session with the residents of Amersfoort and the individual interviews done with residents.

Key takeaways

- Mutual acknowledged absence of green
- Current dissatisfaction with the overall atmosphere
- Wish for greening and biodiversity
- Do experience occasional heat stress and flooding in the city centre
- Most important reasons for greening are appearance, health and climate change
- Other mentioned reasons for greening: coherent city centre and more social interaction
- Shade is an important factor in regard to heat, trees are seen as best choice
- Benches are missing
- Negative outlook on bikes in the street
- Some concerns regarding vandalism of green initiatives
- Own resident ''guerilla actions'' in city centre

In conclusion, there is a desire for greening and an understanding of its potential advantages in the city centre of Amersfoort, but there are also certain present challenges and

concerns addressed by the residents that might influence the design and execution of the greening plans. All should be taken into consideration.

3.2.2. Shoppers interviews

Shoppers were interviewed to gain insight into their viewpoint and interest in regard to greening of the city centre of Amersfoort. The following key takeaways give insight into the most important aspects from these interviews.

Key takeaways

- Shop in city centre for atmosphere and experience.
- Occasional crowdedness had been experienced.
- No recalls of experienced heat or flooding.
- Concerns about maintenance issues in the fall and winter for seasonal greenery.
- Benches are missing.
- Greening and biodiversity are important.
  - Improved air quality
  - Attractiveness and aesthetics
  - Temperature regulation
  - Overall appearance

In summary, while the interviewed shoppers value different aspects of the shopping centre they do stress their need and support for greening efforts. Benefits regarding health and climate are mentioned as key factors.

3.2.3. Expert interview resident initiatives

The residents of Amersfoort can also play an important role in the region by organizing citizen initiatives that increase the greening and sustainability of neighbourhoods. These citizen initiatives can take a long time but show a high success rate, in Amersfoort 12 from the 15 initiatives "partly" succeeded and can thus provide the area with important improvements. Having a group of residents working on citizen initiatives can especially be helpful for the municipality to understand what needs to be done and prevent high amounts of opposition while also having a group of motivated members to work on producing innovative ideas and plans.

3.2.4. OBA

The Ondernemers Binnenstad Amersfoort (OBA) is an association consisting of entrepreneurs in the city centre of Amersfoort, aimed at enhancing the city centre of Amersfoort by collaborating with the municipality to implement projects. Their vision involves transforming the city centre and focusing on making it more liveable. The OBA has initiated projects such as creating a car-free city centre and aiming for a zero-emission city centre by 2025.

32 members of the OBA were contacted from which 5 Interviews were done, these interviews which highlighted a positive outlook on the area's aesthetic and atmosphere, with specific appreciation for flowers. However, concerns were raised about the clutter caused by excessive bike parking and the desire for more green spaces to counteract the predominance of stone paving, which was seen as unattractive. While opinions on greening varied, with some seeing it as crucial for reducing heat stress and aiding climate adaptation, others were indifferent. Biodiversity and the impact of greening on climate change were acknowledged, but not seen as a major concern. Overall, issues like heat stress, flooding, or overcrowding were not identified as significant problem.

From the thesis of Nick Hersbach, it was identified that the entrepreneurs have a positive opinion about trees, green facades, green balconies, and green rooftops. But dislike Shrubs grass and herbs, and climbing plant structures, and there were mixed opinions about the planters.

3.2.5. NGOs

NGOs like 033Groen and Stichting Groen In Amersfoort (SGIA) are identified as potential key stakeholders in greening. 033Groen has a history of successful greening initiatives, leveraging volunteer efforts for creating and maintaining community gardens and green schoolyards, sometimes operating in grey areas of municipal consent. SGIA, known for its environmental advocacy, represents a complementary partner, bringing resistance against eco-damaging projects, a vast network of volunteers, and expertise in preserving natural habitats and air quality.

In total 7 members of 033Groen and SGIA were contacted from which one interview has been done. This interview highlighted the current lack of greenery in the targeted areas, noting the challenges of maintenance and the importance of integrating nature into the urban environment to improve wellbeing and reduce heat stress.

3.2.6. Municipality

Amersfoort's municipality, actively reduces CO_2 and waste, promoting a greener, healthier city through renewable energy initiatives and support for its community (Gemeente Amersfoort, n.d.-b). The municipality realizes that due to climate change we need to find ways to better hold onto water, cool our environment, and swiftly manage rainfall.

3 employees of the municipality were contacted for interviews, but no interviews were obtained.

Initiatives

The municipality is leading initiatives including sustainable and climate focused initiatives, with the help of residents and businesses, which focus on two main strategies: climate mitigation and climate adaptation, adjusting to unavoidable changes like drought and floods. The municipality commits to initiatives like project "steenbreek" that aim to increase urban green spaces, which not only cool areas and manage rainwater but also enhance biodiversity. This collaborative effort involves various partners to boost greenery and biodiversity, crucial for Amersfoort's ability to adapt to climate changes and preserve natural habitats (Gemeente Amersfoort, n.d.-a). One of the projects of the municipality is to stimulate the residents and organizations of Amersfoort to create green roofs in order to increase water retention, cooling, and ecological enhancement in urban areas by providing them with subsidies (Gemeente Amersfoort, n.d.-e). They want to keep whole Amersfoort healthy, liveable, and economically strong by preserving and developing space for greening while making nature, greenery, water, and soil leading (Gemeente Amersfoort, 2023a).

3.2.7. Summary on Stakeholders

Stakeholders in Amersfoort's city centre, including residents, shoppers, OBA, NGOs, and the municipality, all want to see the city centre become greener and more biodiverse. They support green solutions for climate change concerns and express a desire for more trees and sitting places. Positive effects of greening on health are highlighted, with challenges including the need for maintenance and concerns about current bike-related problems. Collaboration is emphasized, with residents, OBA, and NGOs identified as key initiators and contributors to the development and implementation of green initiatives, supported by efforts from the municipality. Residents' initiatives could play an important role in greening the Langestraat and Krommestraat and other areas in the city centre.

3.3. Sub question 3: Green innovations

3.3.1. Plants species

Plants are a good solution to cool down a city. The shade is the best option of cooling down locally, however there are more benefits plants provide to cool down an area. Evaporation of the plants reduces heat, for this to work enough water does need to be available and (Weppelman et al., 2023).

When choosing plant species, it is important to keep in mind which type is planted. Make sure there is a different variety of plants, including trees, shrubs, herbs, and grasses (J. Voeten, personal communication, February 26, 2024). Here the flowering time, the amount of nectar, when they lose leaves and if they damage the building, all play an important role. When creating a plan, it is good to have some evergreen species included, that way the green in the city looks better kept.

Another thing to keep in mind is that plants have to establish, so the first years of growth the maintenance is especially important (P. van Duivenvoorde, personal communication, February 15, 2024). To make sure that the plants settle, good preparation is needed, it is necessary to make the ground a bit loose, for shrubs and other perennials 30 cm is deep enough. While non perennials require 50 cm deep (Zeelandplant, 2019). Since the first layer in the soil of Amersfoort consists of sand, it is beneficial to add some humus when planting these plants.

There are multiple plants that are suitable in Amersfoort. Because it is better to apply soil to the areas that are going to be designated to be planted, the type of soil does not play a major role. Just the effect of a quicker run off, and the fact that the groundwater level is quite low plays an important factor in choosing which plants are suited. And which innovations need to be added to keep plants from water shortage.

An example of a good plant species to be planted in the Langestraat or Krommestraat would be the "Blauweregen", *Wisteria sinensis*, Figure 25. The plant can be placed on the sunny side of the street, and flowers in early summer/may depending on which species is planted, on top of it can provide shade when lead overhead the street. Also, there is a lot of nectar in the flowers which attracts bees (123planten, n.d.).

Figure 25 - "Blauweregen", on the left the Wisteria sinensis, on the right Wisteria sinensis albus . (123planten, n.d.).

3.3.2. Trees

Trees are the most important innovation and plant that helps reduce heat stress. During the day, the perceived temperature is lowered by 9°C underneath the shade of the trees. Trees need a good environment to grow, the most benefits received from the tree, is when the surface area development is maximized. This can be done by planting good tree sand, and making sure there is a water source available to the tree. When the groundwater lever is not high enough crates can be added 1 m into the ground so the tree can reach them (Van Iersel & Voeten, 2023).

It is worth to invest in trees, and the soil and water quality for them. When looking at the Return on Investment (ROI) of a tree with proper space to grow, which is filled with tree sand and there are crates with water sensors is €2.14 to €1.00 invested. While without proper soil and water availability the ROI is €0.18 to €1.00. This was calculated by I-tree using 3 (out of the 17) ecosystem services the tree provides; water retention, air filtering and carbon fixation). Even after 13 years it is already possible to see the effects of proper soil and water availability of a tree compared to a tree without those things (Van Iersel & Voeten, 2023). Figure 26 shows four different scenarios on what choices can be made concerning the place of growth and its water source. It shows that the tree without the proper space and water availability can only grow for 30 years, while a tree with the proper space and soil type with a watering innovation with sensor could grow for 120 years.

Figure 27 shows the break-even points of each different tree scenario. Which shows that a tree without a proper rooting space will never break-even.

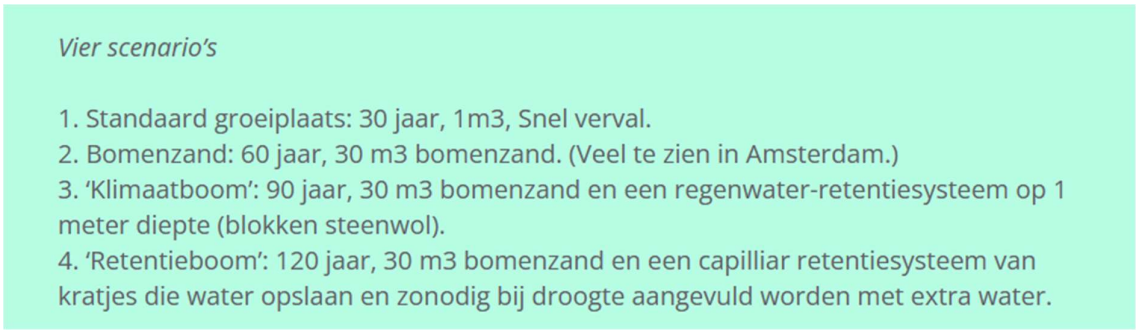


Figure 27 - This figure describes four scenarios of trees. Ranging from a standard tree which does not have enough root space, and no watering innovation to a retention tree which has enough space to grow with tree sand and a watering innovation with a signalling system (Voeten, 2023).

Figure 26 –The calculated break-even point of the different scenario trees (Voeten, 2023).

Characteristics of trees

Trees have distinctive characteristics. The shape and width of the crown, if they root shallow, if they have multiple trunks, height and if they are a "waard" or "dracht" tree are some important characteristics.

General characteristics

The roots of a tree are 1.5 times their crown. When a favourable environment is created somewhere in the soil with enough air, water and nutrients, the roots will grow towards that area. That is why it is important to have a water source at 1 m deep, so the trees root downwards. For a tree to grow properly, 1 m^3 for each year of growth, and 0.5 m^3 for each year of growth when there is water readily available (J. Voeten, personal communication, February 26, 2024).

Species specific characteristics

There are quite some characteristics that differ between tree species. Size and crown transparency are important when planning where and how to plant them. There are three types of trees classified when it comes to their size. Type 1 is a tree where the crown will be 20m in diameter, type 2 is a tree where the crown will be 10m in diameter and type 3 will be 6m in diameter. The bigger the crown the more benefits you achieve by planting it, that is why it is important to see if there is space to plant big trees. The crown can also have different shapes, for narrow streets a columnar crown is advised, while in bigger streets a wider canopy is preferred (J. Voeten, personal communication, February 26, 2024). The airflow in an area is important to reduce heat stress, thus it is important to leave room for air to pass through (Weppelman et al., 2023). The placement of trees are not the only way trees can alter the airflow. The transparency of the crown is important. Also, an open crown means that the side that gets shade does not always have full shade, which is experienced nicely, also in the winter so the sun can come through (J. Voeten, personal communication, February 26, 2024.

The type of trunk can differ between species as well if it has one or multiple trunks. As well as the flowering times. There are trees from the genus *Prunus* flower from March depending on the species (P. van Duivenvoorde, personal communication, February 15, 2024).

To select the correct tree for our purpose the characteristics of the surrounding and the described characteristics above should be considered. When you know how much available space there is and what kind of crown is suitable, the selection tool of Van den Berk or Lappen is convenient to decide which specific tree can be planted there. In that selection tool and in the "Bomentabel" of Hiemstra (2011) the details of the tree can be found.

Preparation and Maintenance

Before planting trees, thought has to go into the preparation of the soil and space needed for the tree to grow. The shape of the available underground space does not matter. Because of the paved ground, rainwater cannot reach the trees properly. For a tree to survive, this must be resolved. For example, rainwater that is collected on surrounding roofs and water that falls on the street can be used. This rainwater should be stored to be used later on as a supply to the trees. The downtown canal can be a suitable place for storage of water. The water area needed for a tree can be calculated by multiplying it by a minimum of 1 times the size of the crown, and a maximum of 1.5 times the size of its crown (J. Voeten, personal communication, February 26, 2024).

When planning for future cables a pipe sleeve/protective tube ("mantelbuis") can be put in the soil when the trees are planted. The result would be that in the future the area the pipe will be free of roots and can be used for new cables. This has to be archived carefully so future cable companies know where to lay their cables. If this solution is not implemented there can be dug 10 times the size of the trunk away from the tree, however, when this happens too much on each side of the tree, the root system can get so damaged the wind might cause it to fall (J. Voeten, personal communication, February 26, 2024).

3.3.3. Innovation inventory

An inventory was made of the (green) innovations that have potential to be applicable to the Langestraat and Krommestraat. To assess the applicability, the innovations have been divided in 4 categories, based on what their main impact is, which can be seen in the overview below. But since innovations suit multiple purposes, each innovation is assessed on four criteria: Improving biodiversity , heat reduction , effect on attractiveness , and contribution to water management . Colours are used in the table to highlight the presence of each criterion per innovation. The pictures are from our ACT group or from Potz et al. (2016).

Vegetation

Street trees

Trees provide many advantages for urban areas and can tackle challenges in multiple areas of interest. Because of their generally long growing time, assessing what tree is best suited is particularly important. When implementation is done right trees can be beneficial to provide shade to cope with heat. Furthermore, the leaves can temporarily store water, and its roots will lead to higher infiltration of the soil. Also, CO_2 uptake of trees can contribute to improved air quality (Pötz et al., 2016). And ultimately, implementation of a variety of trees can contribute to increased biodiversity and attractiveness (Wolf, 2005).

Green pergolas

A pergola is an arched structure consisting of a framework, which can be covered with climbing plants. The green pergola can produce air temperature cooling up to 5 degrees Celsius, through evapotranspiration and casted shade (Chàfer et al., 2020), reducing heat stress. When using varied and endemic plant species, this measure can have a positive influence on the biodiversity. Planting vegetation on pergolas improves the air quality of the surrounding environment (Leung et al., 2011). Implementing green pergolas in a city improves attractiveness (Wolf, 2005).

Climbing plants structures

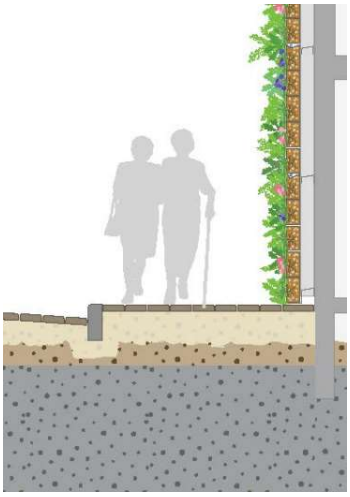
Climbing plant structures can be implemented on places where there is too little space for other vegetation, such as a tree, to root or grow above ground. These structures vary in size and system, which makes it a flexible measure and can be implemented in diverse ways. Climbing plant structures could block solar radiation and provide shade for people and infrastructure. However, this varies on size and shape of the structure. The plants can lower air temperature via evapotranspiration, decreasing heat stress (Lenzholzer, 2015). Climbing plants can improve city attractiveness (Wolf, 2005). Using varied and endemic species, these structures can have a positive effect on biodiversity. Planting climbing plants in cities improves Air quality (Leung et al., 2011).

Facade gardens

Facade gardens are small unpaved strips of open soil with vegetation. This includes anything from trees, and shrubs to grasses and herbs. The vegetation is most often not directly connected with the building facade. Facade gardens reduce heat stress by cooling the air between the facade and the facade garden by

an average of 6.2 degree Celsius. Due to evapotranspiration surrounding air gets cooled as well. (Lenzholzer, 2015). Biodiversity and air quality gets improved by planting varied vegetation including endemic species (Leung et al., 2011). Facade gardens also improve attractiveness (Wolf, 2005).

Green Facades



Green facades include a variety of vegetation measures: Climbing plants, plants in pots and on balconies, and living walls. A green facade is called a living wall when the substrate where the vegetation is rooted is directly attached to the facade (Pötz et al., 2016). Green facades reduce heat stress strongly and can reduce wall temperature up to 30 degrees Celsius (Lenzholzer, 2015). Green facades can contain many different plant species and increases biodiversity. These different plant species contribute to a better air quality (Leung et al., 2011). Green facades improve attractiveness (Wolf, 2005).

Green roofs

Green roofs are divided into two groups, Extensive and intensive green roofs. Extensive roofs require little maintenance and have a light construction. While intensive green roofs have a heavier construction and contains water irrigation systems. Green roofs improve biodiversity, attractiveness, air quality, water management and reduce heat stress (Leung et al., 2011; Wolf, 2005).

Planters

Size, shape and available space for roots determine how effective a planter is to improve biodiversity, attractiveness, air quality, and water management (when connected to other water management systems) and decrease heat stress (Leung et al., 2011; Wolf, 2005) Planters can be larger fixed objects, but also smaller moveable objects. Fixed planters have contact with soil underneath the planter, this makes larger vegetation possible with more shade and evapotranspiration (Lenzholzer, 2015).

Pocket park

A pocket park combines the advantages on biodiversity, water management, attractiveness, air quality and heat stress, due to vegetation (Leung et al., 2011; Wolf, 2005). With the advantages the space between vegetation, usable for seating and other recreational activities, has on attractiveness on the city.

Shrubs

Shrubs is a type of vegetation and reduce heat stress and mitigates UHI (Liu et al., 2021). It does this in three ways: 1. evapotranspiration 2. cooling down passing wind 3. absorbing heat from ground surface (Taib et al., 2016). Shrubs also improve water management, attractiveness, biodiversity, and air quality (Leung et al., 2011; Wolf, 2005).

Grass and herbs

Grass and herbs contribute to decreasing heat stress in two ways, evapotranspiration lowering air temperatures in the environment, and lowering surface temperatures by up to 24 degrees Celsius (Armson et al., 2012; Lenzholzer, 2015). It is however important that grass and herbs are placed in partly shaded areas because the cooling effect is then increased (Armson et al., 2012). Planting a variety of herbs and grasses increases air quality and biodiversity (Leung et al., 2011). Also, grass and herbs in urban space contribute to attractiveness (Wolf, 2005).

Heat

Fountain and mist devices

Fountains are available in a wide variety of systems, in this case a fountain without a base, which continuously holds water, is chosen, because a fountain system with stagnant water can become warmer than its surroundings (Lenzholzer, 2015). Mist installations spray water over the surrounding area. Fountains, when spraying about two meters high, are able to decrease the surrounding temperature about 3 degrees Celsius (Lenzholzer, 2015) decreasing heat stress. Fountains can also have increased cooling effect when in synergy with greenery that prevent solar radiation from reaching the fountain surface (Liu et al., 2021). Fountains when aesthetically pleasing and focused on interaction with children can improve attractiveness of a street (Freeman, 2013) Mist installations, such as a misting fan, provide cooling up to 5 meters from the system. Decreasing air temperature 5-15 degrees Celsius in the surrounding area when installed at 2.4 to 3 meters above ground level, thus decreasing heat stress (Osmond & Sharifi, 2017).

Shading devices

Shading devices, for example freestanding sunshade and shadow curtains, prevent solar radiation from reaching urban surfaces and people. Fixed shading devices, such as shadow curtains, cover the urban surfaces underneath. They are fixed in between two buildings. Shadow curtains prevent up to 98 percent of solar radiation and can be opened and closed according to weather conditions and time of day. When removing shadow curtains at night urban surfaces, such as buildings and pavement, can release heat. This is called night-time cooling. Shading devices reduce heat stress. (Kluck et al., 2020; Lenzholzer, 2015).

Biodiversity and Maintenance

Green maintenance for biodiversity

Urban maintenance can be adjusted to a more focused approach towards biodiversity. By creating policies that not always remove leaves and branches more species could be integrated (Pötz et al., 2016). Furthermore, increased leave surface can lead to an increased uptake of air pollutants, hereby improving air quality (Grote et al., 2016).

Bird boxes and feeders

They can be placed on trees in the case that trees will be implemented in the Langestraat and Krommestraat, or on walls. Therefore, only compatible with other innovations. Bird boxes and feeders will contribute to increasing biodiversity by increasing bird diversity, especially in the winter (Savard et al., 2000). People are fond of watching birds and often place bird boxes near their houses. Placing bird boxes in the city increases attractiveness (Lafortezza et al., 2009).

Insect/bee hotels

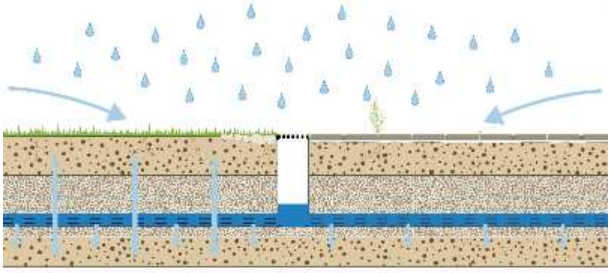
Insect hotels or bee hotels consist of a structure containing various materials insects can nest in, such as bundled plant stem, dead tree material with holes drilled in it, scraps of wood, brick or bamboo, and giant reeds (Geslin et al., 2020). Insect hotels host nesting places for insects such as bees, wasps, beetles, and spiders, and improve pollination service and pest control for the surrounding environment. This will increase Biodiversity.

Usage of material cycles

Residents, visitors, shop owners and vegetation produce a large amount of waste. Organic waste is used to produce compost, which then can be used for the vegetation in the street or for production of biomass, which can be used to make transport within the city more sustainable (Pötz et al., 2016). Use of compost improves soil quality (D'Hose et al., 2014) and contains many fungi, which improves biodiversity (Anastasi et al., 2004).

Water

DT/IT sewer system



An IT sewer system infiltrates rainwater in the subsurface with a tube with holes, that captures rainwater that infiltrates in the soil directly through its pores. This will result in a faster uptake of rainwater, and an improvement in water management. A DT Sewer system consists of a tube that is designed and constructed to bring water to the soil during drought periods, and during wet periods can drain water away out of the system.

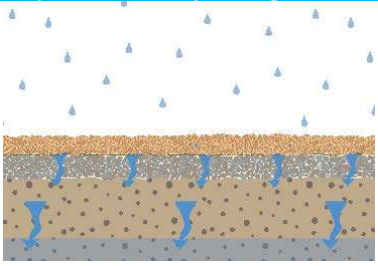
Hollow roads/v-profile

Hollow/v-profile roads can be placed in the middle of both the Langestraat and Krommestraat. The middle of the pavement is relatively lower with the function of discharging stormwater to the sewage system (Pötz et al., 2016). Water will effectively drain during precipitation events, hereby contributing to improved water management. The measure is applicable in the streets without affecting the current infrastructure greatly (Pötz et al., 2016). An example of this can be seen in Alkmaar.

Infiltration crates

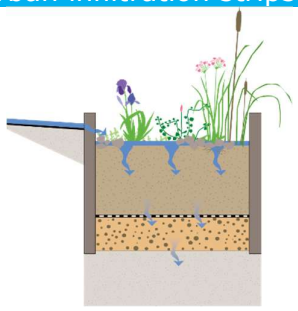
Infiltration crates can be placed under paved areas and function as groundwater reserves that will quickly infiltrate during precipitation events. This will therefore contribute to an improved water management (Rodríguez-Sinobas et al., 2018).

Porous/permeable paving materials



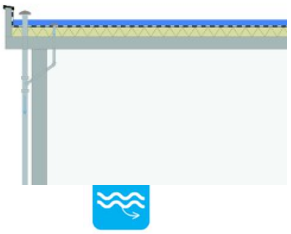
Permeable pavements have a partially open structure that has the function of creating extra space for water to infiltrate. Water management will be improved because of the voids between bricks in the pavement, and the open space between bricks can be used for vegetation. This will help to increase biodiversity and reducing heat stress (Pötz et al., 2016).

Urban infiltration strips



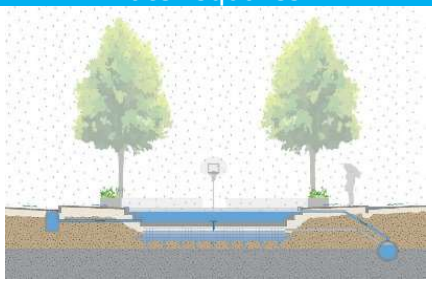
A system of containers with an open bottom, with the function of storing water. Besides providing water management functions, the top can be used to plant vegetation. This quality can contribute to reducing heat stress, improving air quality, and increasing biodiversity (Pötz et al., 2016). Furthermore, green will contribute to attractiveness (Wolf, 2005).

Water roofs



Water roofs have flat surfaces with a higher edged, hereby creating a basin for water retention. Water is further discharged to create space for a following precipitation event (Pötz et al., 2016).

Water squares



Water squares function as a lower lying area within a street, that is mainly paved. The square is normally used as public space but can be used to store rainwater during precipitation events (Ilgen et al., 2019). The square fills up and at the sides infiltrates towards a sewage pipeline, where it can be discharged further. Water squares are mainly used for water retention during precipitation events. Furthermore, it can be incorporated together with other innovations like vegetation and public space that will tackle additional challenges (Pötz et al., 2016).

3.3.4. Innovations in other cities

Alkmaar

For the extended information about the greening innovations in Alkmaar, see Appendix H. The main points we take away from our excursion and interview in Alkmaar are mentioned here.

Tackling such a big change in the city centre requires a lot of input from different parties, but when someone from the municipality is excited about it and someone from the entrepreneur association is willing to go door to door to ask people if they are willing to have green in front of their shops and tell it enthusiastically, it is certainly possible. Something we noticed immediately when walking in de Laat compared to the Langestraat was the atmosphere, Figure 28. Even in the winter, de Laat felt more like a place to be because of the implemented innovations.

Figure 28 - A - de Laat, B - de Laat, C - Boterstraat, D - Langestraat, E - Langestraat, F - Langestraat. ABC are located in Alkmaar and DEF are located in Amersfoort.

Amsterdam

There are a few innovations that we saw in Amsterdam. Figure 30 shows a multitude of innovations found in Amsterdam. A takeaway from the innovations found in Amsterdam is the closer we got to the city centre, the fewer innovations could be seen. Most innovations that were there were not in the soil but in planters, like Figure 30 A, B, E, and I. Another thing we noticed was that there were quite some houses or buildings of entrepreneurs that took initiative to make the city greener. Another thing we saw was that the water in the tram tracks that has permeable ground showed

Figure 29 - A - Tram track that has flooding in the Muiderstraat. B - Tram track with permeable soil without flooding near the Hortus Botanicus.

Figure 30 - All of the pictures depicted here are innovations we saw in Amsterdam. Innovation A & B are closer to the city centre both are planters, A with a climbing plant & B with flowers (Snoekjessteeg). Innovation C & D are façade innovations against a home (Rijnstraat). E is a bench with trees on either side & F is low façade against an entrepreneur building (Muiderstraat). G is an example of trees in the street (Johannes vermeerstraat). H is a green wall, and I is a planter with different kinds of plant (Hortus Botanicus). J is a space of open soil with plants included in the layout of the street (Rijksmuseum). K is a bench with space for plants, and possibly a tree (Hortus Botanicus).

3.4. Sub question 4: Effect on people

3.4.1. Restorative effects of nature on humans

There is empirical evidence that humans prefer natural, green environments over non-green urban surroundings (Ulrich, 1993). A growing body of research often referred to as 'Restorative Environments Research' investigates the beneficial effects that environmental characteristics like flowers, trees and plants have on humans and their health (Ulrich, 1993; Van den Berg, 2005). The healing potential of nature was illustrated in a study on patients recuperating from gallbladder operations, where those with a view of trees from their hospital beds exhibited swifter recovery and improved well-being compared to those facing a monotonous brick wall (Ulrich, 1984).

Restorative Environments Research is guided by two main interpretations: Stress recovery theory (SRT) and attention restoration theory (ART). Stress recovery theory illustrates that the exposure to unthreatening nature has stress reducing effects and can lead to more positive emotional states in individuals (Ulrich et al., 1991). According to attention restoration theory, our direct attention can become fatigued or depleted, but exposure to unthreatening nature, particularly vegetation, can restore our ability to focus (Kaplan & Kaplan, 1989; Kaplan, 1995).

3.4.2. Effects of greenery on urban population/residents

Considering that 68% of the world population is estimated to live in urban areas by 2050, the importance of urban green spaces that provide humans with these restorative experiences is rising (United Nations, 2018). According to a systematic review of studies on the link between human well-being and urban green spaces, green spaces are an integral part of sustainable and liveable cities. Urban green spaces such as green sports grounds, private gardens, green forests, road verges, derelict land and horticulture were positively linked with human well-being (Jabbar et al., 2022). Even small-scale green like pocket parks (smaller than 5000 m2), street trees, green roofs, and flower beds might offer recreational and experiential benefits in cities (Lindal & Hartig, 2015, Mesimäki et al., 2019; Nordh et al., 2009; Peschardt et al., 2012; Peschardt & Stigsdotter, 2013).

The presence of green areas correlates positively with resident satisfaction and (Bonaiuto et al., 1999; 2003) and has been linked to better self-reported health (De Vries et al., 2003). The three studied health indicators were: number of symptoms experienced in the past two weeks, perceived general health, and mental health. In follow-up studies that distinguished green areas and streetscape greenery, the quality and quantity of streetscape greenery proved to be at least as strongly related to self-reported health as green areas. The relationships were generally stronger for quality of the streetscape greenery, which was measured by five elements: maintenance, variation, clear arrangement, absence of litter and general impression (De Vries et al., 2013; Van Dillen et al., 2012).

3.4.3. Differences in types of greenery

As described above, the quality and quantity of green spaces and streetscape greenery can have a positive impact on self-reported health. Furthermore, evidence suggests that people respond differently to different plant types, with many people responding more positively to trees than to other plant types in the landscape (Dwyer et al., 1991; Misgav, 2000). Even distinct species of trees are perceived differently, with people showing a preference for trees with wide, spreading canopies (Lohr & Pearson-Mims, 2006). Research suggests that the psychological benefits of urban public greenspaces increase with the species richness of plants, and to a lesser extent of birds, highlighting the compelling case for prioritizing biodiversity to enhance human well-being alongside conservation efforts (Fuller et al., 2007).

3.4.4. Effects of greenery in the shopping street on customers

A study conducted by Wolf (2005) investigated consumer responses to trees in retail settings. The visual ratings of streetscapes increased with the presence of trees. Streetscapes with well-maintained, large trees obtained the highest preference ratings, despite the plants obscuring other elements such as historic buildings. As mentioned in the master thesis by Nick Hersbach (2022), the study showed that the most preferred commercial streets reached scores comparable to wilderness and outdoor recreational areas. Study respondents indicated more positive behavioural intentions in streets with trees: they stated that they would travel further to reach the business district, visit it more frequently and stay longer. Standardized across convenience goods, shopping goods and specialty goods, respondents indicated a 9% to 12% higher price acceptance for products

in streets with trees. Lastly, it appears that consumers form positive expectations about their shopping experiences well before entering a store. Assessments of both products and merchants tended to be more favourable in streets with greenery. This trend extended to perceptions of product value, quality, and merchant responsiveness as well (Joye et al., 2010; Wolf, 2005).

However, these effects of greenery on shopping streets might be moderated by other factors. For example, greenery may obstruct visibility of marketing-related information or worsen crowding issues. Moreover, it could be perceived negatively if not properly maintained or if it does not complement the surrounding environment (Joye et al., 2010).

3.4.5. Effect of greenery on dense and crowded places

Research in social psychology distinguishes between 'density', which describes the physical condition of spatial parameters objectively, and 'crowding', which indicates "the individual's perception of spatial restriction caused by the interaction of spatial, social, and personal factors" (Choi et al., 1976; Stokols, 1972a, 1972b; Zhang et al., 2023 p. 2). Overcrowding caused by pedestrians, bikes and cars can adversely impact transportation patterns (Zhang et al., 2023), exercise habits (Astell-Burt & Feng, 2015; Wiesenfeld, 1987) and mental health (Gruebner et al., 2017) of people in urban areas.

Research has shown that human crowding can negatively affect consumer shopping satisfaction (Albayrak et al., 2021). Zhang et al. discovered that people's physiological stress response increased when exposed to human crowds in commercial and transit zones, but not in green and blue spaces. One explanation is that the surrounding environment serves as a 'buffer', mitigating the impacts of overcrowding (Zhang et al., 2023). As outlined in prior research, natural elements within cities have been shown to have a calming effect on human stress levels (Jiang et al., 2014; Wolf et al., 2020).

Greenspaces are also thought to alleviate stressors caused by over-densification, given that residents of cities often live busy lives and face various stressors (Peschardt & Stigsdotter, 2013). Additionally, it has been observed that greenery at eye level helps counteract the detrimental impact of urban density on the overall life satisfaction of older adults. These findings underscore the importance of enhancing the environments of high-density neighbourhoods and advocating for the promotion of eye-level greenery in urban areas with high population densities to foster age-friendly cities (He et al., 2022).

3.5. Main question: Suitable innovations

"Which green innovations are best suited for improving water management, biodiversity, heat stress management and attractiveness of the Langestraat and Krommestraat in Amersfoort, which are viable when considering current challenges, limiting factors in the immediate surroundings and different stakeholder viewpoints?"

3.5.1. List of innovations

Here we list the innovations and make a distinction between the innovations we would advise, the innovations that could be added under certain conditions and innovations that we rejected in our project. The reasoning behind the advised and optional innovations is given below; the reasoning behind rejecting the other options is given in Appendix I. The way in which the advised innovations could best be combined, is described in our advice.

Table 4 - List of advised, optional and rejected innovations.

Advised innovations	Optional innovations	Rejected innovations
Street Trees	Bird boxes & Feeders	Green pergolas
Climbing Plant Structures	Insect hotels	Green façades
Façade Gardens	Hollow Roads	Pocket park
Shrubs Plants and Grass	Water Roofs	Fountains
Planters	Green Roofs	Shading devices
Infiltration Crates		Green maintenance
Infiltration Strips		Usage of material cycles
DT/IT sewer system		Permeable pavement
		Water squares

Advised innovations

- **Street Trees:**
  - **Benefits:** Planting trees in the streets is a well-suited innovation as it has many beneficial impacts: it reduces heat stress, improves water management, improves air quality, contributes to biodiversity and attractiveness. The stakeholders also indicated that they like greening which fit with this innovation.
  - **Requirements:** Due to the low ground water, trees would need to be implemented in combination with other water management systems. In the Krommestraat, trees could be placed in planters to enable moving them out of the way temporarily for things like construction projects. The trees also need to be selected for size and shape of both the crown and the root system. For potential future cables, empty tubes can be placed in the ground so no digging too close to the tree will be required.
  - **Limitations:** The main conflict is with transportation: loading, unloading, and cycling needs to be restricted due to the limited space. The underground shows that it is possible to plant trees in the Langestraat and the heritage is not directly affected.
- **Façade Gardens:**
  - **Benefits:** Façade gardens reduce heat stress, improve attractiveness, biodiversity, and air quality. The main benefit of façade gardens is that they are easily implementable when dealing with heritage and that they take up little space to enable traffic to go through.
  - **Requirements:** building owners need to agree on it.
  - **Limitations:** The reduction of heat stress and improvement of attractiveness and air quality are less than with trees.
- **Climbing Plant Structures:**
  - **Benefits:** Climbing plant structures is a well-suited innovation as it has multiple benefits: they reduce heat stress, increase attractiveness, biodiversity, and air quality. The main strength that makes this innovation well suited is that it can be planted in places where there is little space. This makes it applicable in the Krommestraat which is smaller and aligns with stakeholder viewpoints on crowdedness as well as enabling traffic to go through.
  - **Requirements:** Building owners need to agree on it.

    - **Limitations:** The reduction of heat stress is less than with trees, which provide shade.
- **Shrubs Herbs and Grass:**
    - **Benefits:** This innovation is well suited as it reduces heat stress, improves water management, attractiveness, biodiversity, and air quality. These plants are suitable as they can be combined with trees and façade gardens to provide more benefits in a small amount of space. Flowering plants can be chosen to increase the attractiveness even more and align with the stakeholder viewpoints.
    - **Requirements:** They will likely need similar watering systems as trees, or watering by hand, in summer. The soil needs to be protected from people walking, cycling, or driving over it.
    - **Limitations:** The effects on heat stress, water management and air quality are less than with trees, but they work well in combination with trees.
- **Planters:**
    - **Benefits:** Movable planters can be combined with the aforementioned innovations and enable these innovations to be moved. This is especially helpful in the Krommestraat which is smaller.
    - **Requirements:** They will likely need extra watering in summer.
    - **Limitations:** Small planters retain little water and therefore contribute little to water management. For trees, planters also limit the root growth, which is a restriction on the trees that can be chosen.
- **Infiltration Crates:**
    - **Benefits:** This innovation has as sole function to improve water management but is very important when in combination with trees as it can serve as a water basin during droughts and improve infiltration during periods of precipitation.
    - **Requirements:** Needs to be in combination with plants to be effective.
    - **Limitations:** -
- **Urban Infiltration Strips:**
    - **Benefits:** This innovation can be used for façade gardens or green that is planted in the road. It leads to improved water management by allowing infiltration into the ground.
    - **Requirements:** Due to the low ground water in Amersfoort, this should be combined with infiltration crates that retain the infiltrated water. The soil may need to be protected from people walking, cycling, or driving over it.
    - **Limitations:** -
- **DT/IT sewer system**
    - **Benefits:** Going from a combined sewer system to a separated sewer system would improve water management by making it easier to drain storm water. These systems can also be used to improve the watering of greenery with cleaner water.
    - **Requirements:** Installing a new sewer system would require a large-scale construction project.
    - **Limitations:** The new system is expensive and costs a lot of time to build.

<u>Optional innovations</u>

- **Bird boxes and Feeders:**
    - **Benefits:** Bird boxes and feeders support biodiversity They are inexpensive and easy to place which makes them a good innovation to combine with others.
    - **Requirements:** They work best when other green innovations already exist close by so the birds can also live in the area.
    - **Limitations:** They do not have a clear effect on heat stress, water management, air quality or attractiveness.
- **Insect hotels:**
    - **Benefits:** Insect hotels can greatly increase the biodiversity and are easy to place.
    - **Requirements:** Other than birds, most insects travel no more than 70 metres for their food, so insect hotels would only be effective if there is plenty of greenery with nectar producing flowers close by.
    - **Limitations:** They do not have a clear effect on heat stress, water management, air quality or attractiveness.

- **Hollow Roads:**
    - **Benefits:** Hollow roads improve water management by draining rainwater better from the street. It does not influence the layout of the city on factors such as crowdedness and traffic management. When substantial changes need to be made to the underground infrastructure it is possible to combine that with implementing this innovation.
    - **Requirements:** The low point in the road should be connected to the sewer system.
    - **Limitations:** -
- **Water Roofs:**
    - **Benefits:** Water roofs have the sole function of water management but can be a great addition to make an automatic water system. The water roofs can be combined with other innovations such as trees which makes it a valuable combination to prevent flooding and support greenery.
    - **Requirements:** Water roofs need roofs that can support the weight and building owners need to agree on it.
    - **Limitations:** Many monumental buildings will not be suitable for the weight of water roofs, as well as for the changes that would need to be made.
- **Green Roofs:**
    - **Benefits:** Green roofs have the same function as the water roofs but also decrease heat stress in the buildings itself, as well as increase biodiversity and air quality. Green roofs can also be linked with other green innovations to provide water management.
    - **Requirements:** Green roofs need stronger roofs than water roofs, they likely need extra watering in summer and building owners need to agree on it.
    - **Limitations:** Many monumental buildings will not be suitable for the weight of green roofs, as well as for the changes that would need to be made.

3.5.2. Trees

In Figure 31 & 32, the green areas indicate all locations where a tree could be planted when considering the underlying cables and pipelines for a small part of the Langestraat. Figure 33 shows a cross section of the underground situation. A map for the total available space for the planting of trees on the Langestraat can be found in Appendix J.

Figure 31 - The available space for the planting of trees considering a buffer of 1 meter around the cables and pipelines.

Figure 32 - The available space for the planting of trees considering a buffer of 2 meters around the cables and pipelines

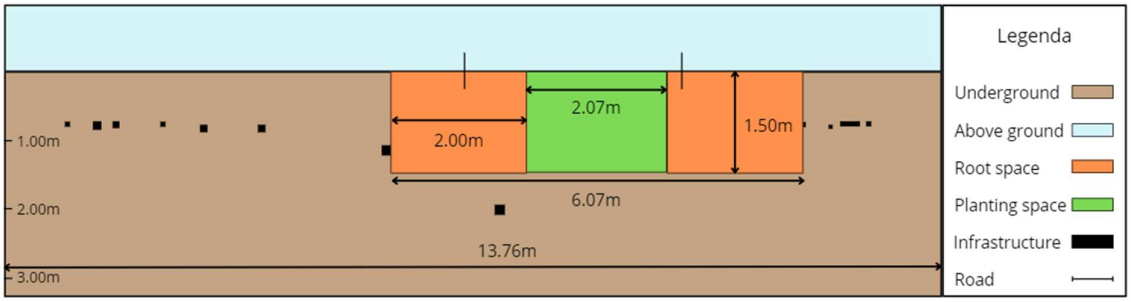


Figure 33 - Shows a cross section in the Langestraat. Visualizing the underground situation for a tree, in case of planting space and root space. In this case it can be seen that the planting space of the tree is entirely within the existing road.

4. Discussion

4.1. Key findings

The findings of this research have provided insight into the green innovations that are suitable to improve water management, biodiversity, heat stress management, and attractiveness of the Langestraat and Krommestraat in Amersfoort. Considering the current challenges and limiting factors of Amersfoort, as well as the viewpoints of stakeholders, the following green innovations were considered most relevant: street trees, climbing plant structures, façade gardens, shrubs, plants and grass, planters, infiltration crates, infiltration strips and a DT or IT sewer system. The cables underground permit planting trees on parts of the street, depending on the size of the tree, but these do need to be placed together with infiltration crates and a watering system to support them.

4.2. Implications of the findings

The master thesis report ''Cool retail: towards novel, climate-resilient shopping streets'' by Nick Hersbach served as the starting point of Science Shop's project (Hersbach, 2022). Hersbach's focus was on climate-resilience and retail, and their synergies and trade-offs, whilst researching suitable interventions. The interventions in his thesis aimed to tackle climate scenarios with extremes in heat and rainfall. His insight on urban heat, flooding and green interventions served as a basis for this report. The project 'A green heart for Amersfoort' built on the work of Hersbach, by adding the viewpoints of different stakeholders, biodiversity, water management (including the sewer system), and the attractiveness of greening the Langestraat and Krommestraat, and considering the current challenges and limiting factors in the immediate surroundings. Moreover, this research investigated the effect of greening on people, including the effect on mental and overall health.

Hersbach's thesis included the opinion of one specific stakeholder, the shop owners. He took the current acceptance of climate resilient interventions by the shop owners into account. His findings regarding the entrepreneurs correspond with our findings, which mainly include that many shop owners advocate for greater greenery in retail streets. They prioritize short-term interventions for optimal corporate performance. This report also includes the viewpoints and interest of the stakeholders OBA, municipality, residents, and shoppers.

Hersbach's thesis describes 18 possible interventions that can contribute to the climate resilience of the shopping street. This report adds to that by describing 22 implementable innovations, with a focus on the Langestraat and Krommestraat in Amersfoort. These innovations include 10 innovations on vegetation, 2 on heat, 3 on biodiversity and maintenance and 7 innovations for water management.

4.3. Limitations

This research is subject to several limitations regarding assumptions that were made, the generalizability of stakeholder viewpoints, and the scope of the project. Furthermore, there are limitations regarding the data collection and the GQIS flowchart of the report.

The literature study conducted for the introduction and various research questions includes information and studies from different countries. Since not all the study results are from the Netherlands, the transferability of the information to the projects location in Amersfoort is limited and assumptions were made. For example, based on data on heavy metal occurrence in Dutch soil, the assumption was made that there are heavy metals in the soil in Amersfoort. Furthermore, given the evidence of globally increasing urban floodings due to combined sewer overflow, we have assumed that these issues will increase in the Langestraat and Krommestraat as well. The drawing of the cross section of the Langestraat and Krommestraat is based on an assumption on average street width. The representation on paper is not completely accurate due to the inability to precisely represent distances smaller than one vertical or horizontal square.

The generalizability of the results on the stakeholder viewpoints is limited due to a relatively small sample size of the various stakeholders. The stakeholders that agreed to participate in interviews and the resident facilitation session might be more interested in greening than other stakeholders. Therefore, it is possible that they do not represent the opinions of all stakeholders.

The interviews with OBA members and the NGO were conducted through email, which did not allow for follow-up questions, whereby the results offer limited insights. No interview was conducted with the municipality, which is why the viewpoints are solely based on information from their website.

It is beyond the scope of this study to investigate the regulations on monumental buildings and other real estate in depth. As the heritage rules are open to interpretation, an independent committee of the municipality assesses the allowed alterations for each building individually. Therefore, no specific regulations were considered for the evaluation of greening innovations. The specific disadvantages of the green innovations were also only considered to a limited extent. The use of bicycles in the shopping streets was not the focus of the research project. However, based on information gathered while researching the challenges, including stakeholder interviews, the vision for this report prohibits bikes from the Langestraat and Krommestraat during shopping hours.

The gathering of greening innovations in Amsterdam was constrained by the fact that no expert agreed to be interviewed. As the results from the visit to Amsterdam were only based on images, they are not as well-founded as those from Alkmaar. The same limitation arose for research question four, which concerned the effect of greenery on people, as no expert could be found to conduct an interview.

The methodology explaining the QGIS flowchart (see Figure 6) is written to be replicated for further preparation of maps in Amersfoort. However, it should be noted that a basic knowledge of GIS and the construction of maps is needed to understand the steps and tools described.

These limitations are important to recognize on which assumptions the results of the project are based and where limits were drawn regarding the scope. The limitations also result in recommendations for further research.

4.4. Recommendations

Future research should expand on the results of this project in order to gain a more holistic view on green innovations suitable for Amersfoort.

Large parts of Amersfoort have a good reputation regarding the presence of green within its urban design, which should be investigated further to see how the innovations in the Langestraat and Krommestraat relate to those. Moreover, more emphasis should be placed on the disadvantages and obstacles of the green innovations. This report did not investigate the financial aspects, such as the cost of green innovations or maintenance, or whether funding is available. We suggest that the policies on loading and unloading of goods will be reviewed and possibly changed in order to make more space for green innovations.

More research is needed to investigate details for plant species. The municipality of Amersfoort plans to publish an action plan regarding plant and animal species called 'DOP of biodiversity', which could be helpful to deepen the insights in this area. We recommend making the planting plan (beplantingsplan) for the areas that will be greened. We propose contacting the planner of the Orlyplein in Amsterdam to examine their planting plan because they have plan where there is always something green. Creating a calendar of the planting plan showing when plants shed their leaves, when they begin to develop new leaves, and when they blossom could ensure that the green spaces look good throughout the year.

Additionally, further research is needed to investigate the impacts of current innovations as well as additional innovations on circularity of energy in the city centre of Amersfoort. As Pötz (2016) stated: "There is still much unused potential in sustainable decentralized urban energy and heat production".

Furthermore, while the need of improving air quality through green innovations is emphasized, there is no clear assessment of the existing condition of air quality in Amersfoort. To accurately examine the effect of green innovations on air quality, a thorough investigation of existing and predicted air quality in Amersfoort is required.

We would not advise future researchers to investigate compact soil and specific nutrients and pollutants in the soil because we were unable to obtain this information. Moreover, most plants would benefit from additional soil being added during planting.

Considering future research, we propose that the social impact of green innovations should be taken into account more and more literature research is required to provide this. Additionally, we propose that for future selection of innovations for the Langestraat and Krommestraat the possibilities of combining seating with green innovations should be considered. Because of the ambition to create an integrated design for the Langestraat and Krommestraat, this could be a component that clearly considers the social aspect of implementing green innovations.

5. Conclusion

This research investigates the challenges and opportunities for implementing green innovations in the Langestraat and Krommestraat of Amersfoort. There are increasing issues of heat stress, flooding due to heavy rainfall, and lack of greenery which all result in a need for environmental compatibility of the main shopping streets. Integrating green solutions into these streets will mitigate environmental stress factors while creating a more attractive, healthy, and sustainable city for its residents, shoppers and the other stakeholders.

5.1. Summary of Main Points

5.1.1. Challenges and Limitations

Heat stress, extreme precipitation, biodiversity loss, and the impact of online shopping on urban retail are identified as primary challenges that the city centre of Amersfoort is facing.

Additionally, the infrastructure and transport are significant limitations that are taken into account together with limitations of heritage within the urban landscape of Langestraat and Krommestraat. The underground infrastructure and the streets' design to accommodate various modes of transport show to be a constraint for the implementation of green innovations.

The list of green innovations created shows the identified challenges and are used as an overview of possibilities. These innovations, ranging in scale and scope, aim to reduce heat stress, manage precipitation, enhance biodiversity, and increase attractiveness.

5.1.2. Stakeholder Perspectives

The identified stakeholders include residents, shoppers, the OBA, NGOs, and municipality, All the stakeholders desire a greener, more pedestrian-friendly city centre. The main opinion among these groups aims towards an attractive urban environment that balances urban demands with green solutions. Environmental impact in the city centre of Amersfoort is recognised by different stakeholders, this seems to be the main driver for their wish for green solutions. These opinions are backed by the insights that there are positive effects of greening on human well-being, including stress reduction, improved mental health, and increased satisfaction and spending in green shopping streets. Apart from the environmental and health solutions that greening offers, attractiveness and atmosphere are important factors amongst the stakeholders as well.

The most mentioned concrete practicalities by the stakeholders include a wish for more benches, trees as the main greening solutions and a wish for less bikes in the city centre (parked bikes as well as the traffic of bikes in the streets).

Key insights from stakeholders highlight the need for a collaborative approach in improving the Langestraat and Krommestraat and show the potential for green spaces to increase urban liveability, biodiversity, and social cohesion. Enhanced by shared knowledge and effort the residents, OBA, and NGOs can organize valuable initiatives that create and implement green innovations.

5.1.3. Solution and Recommendations

These challenges and limitations are incorporated into the green innovation map and the vision. The green innovation map shows potential areas for green innovations within Langestraat. This map can be used to guide the strategic placement of greenery and other ecological innovations to optimize environmental benefits and urban improvements. The vision that we created aligns with stakeholder interests and addresses the identified challenges. This vision integrates green innovations in a manner that respects the area's limiting factors and the diverse needs of its users. Ultimately, this vision and the innovation map offers a framework for achieving a greener city centre and can be used as a starting point to open the discussion with different stakeholders. We believe there are many opportunities to make the city center of Amersfoort greener. As long as all parties cooperate, all challenges can be tackled, and the city center of Amersfoort can change from a place to buy into a place to be.

More research is needed to investigate details for plant species and the effect of green innovations on existing infrastructure. For this we recommend continuing our work on communicating with other cities where a similar plan has already been created and executed. Extended work and recommendations will be provided in the advice.

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Appendices

Appendix A- Cross section Langestraat

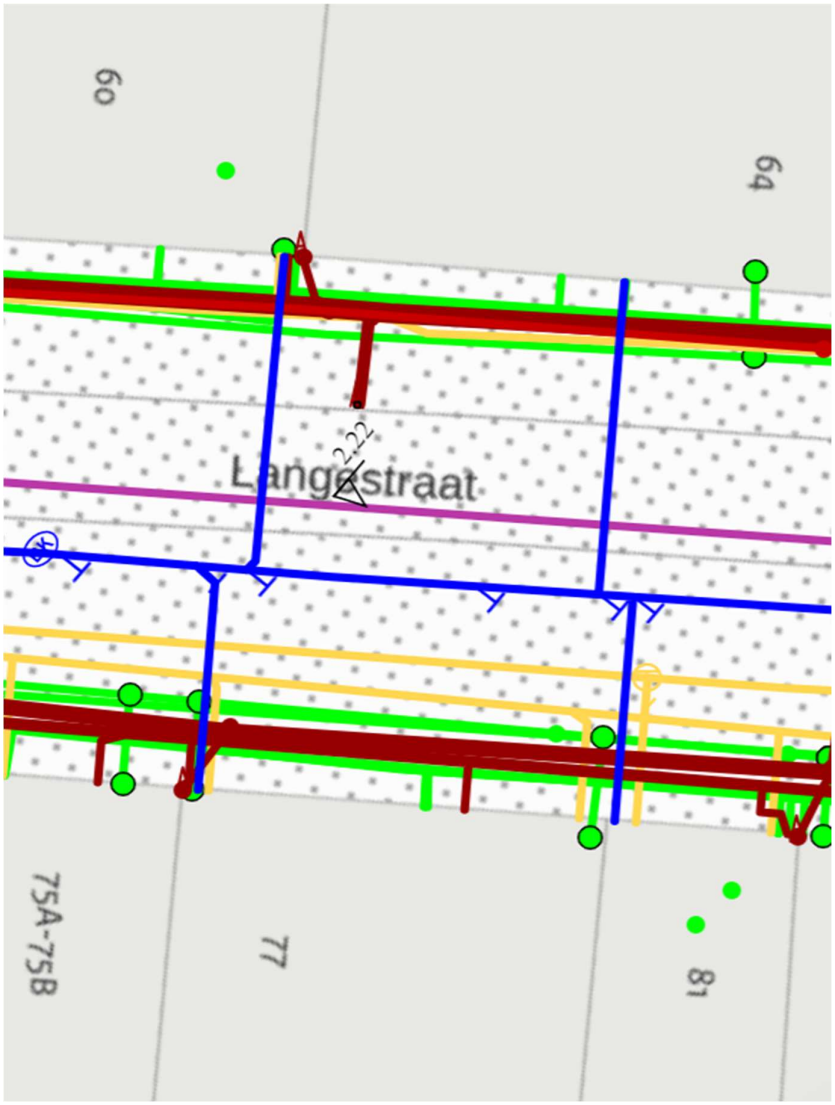

Figure A.1 - Part of the Langestraat were the cross section figure is based on

Appendix B- Data cross section Langestraat

Table B.1 - Infrastructure distance, depth and width in meters and converted to pixels.

Infrastructure Langestraat	Distance relative to street (m)	depth (m)	width (m)	distance in pixels	depth in pixels	width in pixels
Street width and depth	0	0	13.76	0	0	5500
Drinkwater	5.64	1.10	0.15	2255	440	60
Laagspanning	1.44	0.75	0.16	576	300	64
Laagspanning (stedin)	1.16	0.75	0.10	464	300	40
Riool	7.40	1.75	0.30	2958	700	120
Gas (L)	2.73	0.80	0.80	1091	320	320
KPN (L)	2.15	0.75	0	860	300	0
Reggefiber (L)	0.90	0.75	0	360	300	0
Ziggo (L)	0.90	0.75	0	360	300	0
Ziggo (R)	1.00	0.75	0	400	300	0
Gas (R)	1.60	0.80	0.80	640	320	320
KPN (R)	1.91	0.75	0	764	300	0
Reggefiber (R)	0.90	0.75	0	360	300	0
Laagspanning (R)	1.16	0.75	0.29	464	300	116

Appendix C – QGIS Tools descriptions

1. **Add data**: To use data in a QGIS project, the first step is loading this into the project. By going to Project --> Data Source Manager many options are provided to select data. In this case, vector data should be selected.
2. **Add Basemap**: To make the data you have added understandable, a basemap is added to give that is laid under your data to show the geographical location of your data. In this case, go to plugins and look for QuickMapServices. Download this plugin, click on it after downloading and search for a basemap that suits your project best.
3. **Select features by value**: In the top left of your project, press 'select features by value'. To select the different follow types of cables and pipelines, select 'contains' and enter the following terms into 'fid': 'GasOlie', 'Elektriciteit', 'Water','Riool', and 'Data'. After selecting one of the terms, right-click on the layer in the layer panel and select 'create layer of selected values.'
4. **Create Buffer:** To select the 'Create Buffer' tool, go to Vector --> Geoprocessing Tools, and select Create Buffer. Select one of the newly created layers as input layer, adjust the distance of the buffer, and press Run. Repeat this for every layer described.
5. **Merge Vector Layers:** Go to Vector → Data Management Tools and select 'Merge Vector Layers'. In this tool, select all created buffer layers, and press Run. The merged layer is loaded into your project. This has created 1 layer that includes all separate buffers.
6. **Dissolve:** Go to Vector → Geoprocessing Tools and select 'Dissolve'. Use the merged layer as input, and press Run. This has created one polygon of with all buffers together.
7. **Duplicate Layer:** Hover over the dissolved layer and select 'Duplicate Layer'. This creates a copy of the layer that is added to the project.
8. **Delete holes:** The dissolved vector on the Langestraat has multiple holes. These need to be removed from the copy. Go to Processing → Toolbox, search for 'Delete Holes', and select the tool. Use the copy as input layer, and press Run. The clean layer without holes is added to the project.
9. **Difference:** To create the layer with the remaining space on the Langestraat falling outside of the Buffers, the difference is used. Go to Vector → Geoprocessing and select 'Difference'. In this tool, use the copy with deleted holes as input layer, and the previous dissolved layer as Overlay layer. Press run and save the layer to a file. The result shows the areas that are available for planting trees for the selected buffer input.

Appendix D – List of species

Table D.1 - List of species present in the city centre in the period from 2011 to 2018 (Beers et al., 2019).

Species	Scientific name	Group
Steenbreekvaren	*Asplenium septentrionale*	plant
Tongvaren	*Asplenium scolopendrium*	plant
Dotterbloem	*Caltha palustris*	plant
Gele Helmbloem	*Pseudofumaria luteo-alba*	plant
Klein Glaskruid	*Parietaria judaica*	plant
Bruin Zandoogje	*Maniola jurtina*	insect (butterfly)
Hooibeestje	*Coenonympha pamphilus*	insect (butterfly)
Oranjetipje	*Anthocharis cardamines*	insect (butterfly)
Weidebeekjuffer	*Calopteryx splendens*	insect (damselfly)
Blauwe reiger	*Ardea cinerea*	bird
Grote bonte specht	*Dendrocopos major*	bird
Grote gele kwikstaart	*Motacilla flava*	bird
Huismus	*Passer domesticus*	bird
IJsvogel	*Alcedo atthis*	bird
Ooievaar	*Ciconia ciconia*	bird
Veldleeuwerik	*Alauda arvensis*	bird
Zwarte roodstaart	*Phoenicurus ochruros*	bird
Boerenzwaluw	*Hirundo Rustica*	bird
Huiszwaluw	*Delichon urbica*	bird
Boomvalk	*Falco subbuteo*	bird
Buizerd	*Buteo buteo*	bird
Slechtvalk	*Falco peregrinus*	bird
Sperwer	*Accipiter nisus*	bird
Torenvalk	*Falco tinnunculus*	bird
Eekhoorn	*Sciurus vulgaris*	mammal
Egel	*Erinaceus europaeus*	mammal
Gewone dwergvleermuis	*Pipistrellus pipistrellus*	mammal (bat)
Laatvlieger	*Eptesicus serotinus*	mammal (bat)
Rosse vleermuis	*Nyctilus noctula*	mammal (bat)
Ruige dwergvleermuis	*Pipistrellus nathusii*	mammal (bat)

Appendix E – Extended results from a workshop and interviews with residents and shoppers

Residents and shoppers' session Amersfoort

7 Residents and shoppers of Amersfoort participated in a workshop to gather information and ideas about greening solutions for the city centre of Amersfoort. The following paragraph gives insight in the most important and useful insights from this session.

Insights

The workshop was valuable for sharing and gathering ideas, and it highlighted that things are happening, encouraging participants to join conversations about regreening. The shoppers and residents that were present and the main points emphasized that current views on green aspects in the Langestraat and Krommestraat are almost completely absent, everyone agreed that this should be improved. They would like more green for health reasons and for the overall appearance of the city centre. The creation of shadow with the use of green initiative was an important aspect of this. Ideas for green initiatives shared were green public roof terraces, a green walking route through the city centre, places to sit mixed with art, façade greening and cables with hanging green above the street.

Other opinions of the participants are that many did not like the bikes in the shopping street, including the fact that many people ride their bikes to fast. Also mentioned is that vandalism is not too bad according to most participants, but with regards to the night life the green solutions should be sturdy. As of now, windowsills are used to sit on. More benches would be appreciated by the participants to create a shaded rest place.

Role of residents

Participants felt empowered to participate and contribute throughout the workshop, indicating that incorporating residents in future regreening efforts could result in shared enthusiasm, a clearer vision of ideas, and a better knowledge of practical goals. The session advised that participants' thoughts and ideas should be compared and combined with those of the OBA to assist the municipality in assessing both parties' objectives. Most participants expect that interventions are implemented by entrepreneurs and residents, with the municipality providing support through incentives and laws. The participants indicated that entrepreneurs may and should seek assistance from residents when necessary and possible. Future collaboration between OBA, Vrienden van de Kamp, residents, and the municipality can excite and enthuse these stakeholders, demonstrating a willingness to adapt, interact, and participate from the residents.

Residents of the city centre

3 residents of the city centre of Amersfoort were interviewed. Two of the residents interviewed were female with an age of 66 and 65 and one male resident with the age of 77. The interview questions were formulated to understand the viewpoints and interests of the residents regarding the Langestraat and Krommestraat and the greening of this area in the city centre. With the insights from the interview's possible challenges, limitations and other hurdles can be recognized before implementation of any green initiatives.

Greening and attractiveness

All interviewed residents of the city centre of Amersfoort explained that they appreciate the green that the city centre already has and would really like to see more green because they all find it important. Resident 1 said that she finds greening of the city centre important for her living environment. Resident 3 states that he sees greening as crucial for the quality of life, atmosphere, and the absorption of particulate matter. According to this resident greenery in the city contributes to better air quality and a more pleasant environment. Resident 2 explains that she thinks more green will increase the attractiveness of the city centre to the public. Also, she sees greening as essential for the health of the city centre residents and for the future of the city to keep it liveable.

By all residents green is seen as a way to improve the quality of life and the appearance of the city. During the interviews trees and plants are mentioned as good greening options for the city centre. Flowers are mentioned but are seen as a less good option because of the high maintenance and because it provides no shade, which a tree would according to the residents. Specific areas such

as the Langestraat are mentioned as areas for improvement, with calls for more greenery, seating areas, and art to make the area more attractive.

"There is a distinct lack of greenery in certain parts of the city, which makes the living environment less pleasant." – Resident 1 "I strongly favour greening the area to make it more attractive to the public and residents. Greening is a way to improve the liveability and appearance of the city." – Resident 2

Biodiversity

Resident 1 indicates that biodiversity is very important for her. Flowers and the insects it attracts are something that she is interested in because she herself, with her neighbour(s), greens her own living environment with small actions; ''guerilla actions'' as she calls them. These are on own initiative and get tolerated by the municipality. These actions are, for example, the placement of small trees and replacing pavement with greenery in her street. Resident 3 explains that the presence and importance of biodiversity, such as variation in birds and other animals, is appreciated. It contributes to the enjoyment of life in the city.

"I think biodiversity is very important. I enjoy the variety of birds you see. The most important animal life you see in the city centre is actually the birds and less other animals or insects.'' – Resident 3.

Social cohesion and atmosphere

All residents in this study indicate a link between cohesion of the city and/or of its people and the greening of the city centre. Resident 1 explained that in her eye's greenery contributes to a pleasant living environment and promotes social cohesion. She finds it pleasant and important that people come to her and that they can enjoy green places in the city together. She describes that benches and other places to sit in the Langestraat and Krommestraat in combination with shadow would be good for increasing the social coherence in the city as well as important for people to rest. Resident 3 also recognises that there is a lack of facilities such as seating areas. She also mentions public restrooms, which in combination with more seating areas makes staying in the city more comfortable. As of now, according to resident 1 and 2, visitors of the city centre choose windowsills of shops to sit down on.

The atmosphere in the Langestraat and Krommestraat are at the moment not valued high by the residents. Also, according to resident 2 the route from the station to the city and within the shopping area is not very attractive. Apart from that she explains that she views the Krommestraat positively because of its diversity and togetherness among business owners, making it an attractive shopping area. All interviewed residents believe that greening these streets will have positive outcomes on the overall atmosphere of the area of the Langestraat and Krommestraat. Respondent 3 likes to see a combination of a pleasant atmosphere, monumental buildings, and the connections between squares that show the city as a whole, as opposed to just a shopping street.

"I think greenery is an important part of the city's atmosphere. Comfort through more greenery is an important part of that'' - Resident 3

Climate (change) – heat stress and flooding

There is a strong preference for greening within the city, not only as a means for aesthetics and liveability but also for practical benefits such as air quality improvement and heat reduction. The emphasis on greening indicates a critique of urban petrification. Water runoff issues and heat island effects suggest an awareness of the negative effects of too much petrification.

Greenery in the city is seen as essential for a pleasant living environment. All residents that were interviewed indicated that they are aware of climate change and that that has consequences for Amersfoort and its city centre as well. Resident 1 is very aware of the climate and concerned regarding climate change and its impact on urban life, which may discourage people from coming to the city. She finds the greening of the city centre important for cooling and making it more pleasant, especially during hot summer days. Resident 2 described the current situation as a "stone desert," with a lack of greenery and trees, which exacerbates summer heat and reduces liveability. Trees and greenery are seen as important for providing shade and reducing heat in the city. Heat is specifically mentioned in the context of greening and the need for shaded areas to reduce downtown

temperatures and making the city comfortable during hot periods. Respondent 1 explains that the squares with trees in the city centre are full of people in summer because everyone looks for areas with shade to sit down and rest.

"People keep following the shadows to keep it up. You have that here in the summer, too. Then people all walk on the side of the street, because then you cannot actually be on the street itself. I think that also affects people in the sense of, then they might start shopping online or not coming to town anymore. Because it is just too hot." – Resident 1

Resident 2 says she experiences flooding in the city centre, exacerbated by climate change. She explains that the soil is saturated, making it difficult for water to leave and leaving puddles after heavy rains. This is perceived as a problem, especially when combined with the heat in the summer months. Resident 3 also experienced water drainage and maintenance problems, these lead to puddles on streets and poor conditions for pedestrians.

Challenges

Resident 1 experiences nuisance due to the large number of bicycles in the downtown area, both parked on the street and cycling through pedestrian areas. She feels that there are too many bicycles and that this contributes to a less pleasant city experience. The people biking in the city centre are going to hard sometimes which can be dangerous in her eyes. Also, by resident 2 attention is being paid in the interview to the bicycle parking situation in the city centre. She does recognize that many bicycle parking spaces have been created but she thinks that the bikes are still not parked in such a way that they do not interfere with shoppers.

Residents 1 and 2 would like to find different solutions for the parking of these bikes, with an emphasis on locations outside the Langestraat and Krommestraat, while respondent 3 would not fully remove the bike parking spots but indicates that he would move the parking spots within the street to encourage the shopper's freedom of movement from store to store. Resident 3 thinks that the way it is positioned now, the bikes block the stores.

"Although many bike parking spaces have been created, it remains a challenge to park bikes in a way that does not interfere with shoppers, especially during off-peak hours." – Resident 2

The current layout of streets and shared space is perceived as problematic by resident 3, especially the dominance of certain traffic and the lack of clarity about rules. Respondent 3 feels that better policies and enforcement are needed. Nuisance from car traffic, and noise from cars and motorcycles is also perceived as a problem. Again, respondent 3 said there is a need for better regulation and enforcement.

Resident 2 mentioned that when greening a city, you should take the night life into consideration. Flowers and small plants and all other green should be vandal-proof, otherwise they will be destroyed. Another challenge that should be looked at according to this resident is what is feasible and what fits in terms of sun, shade, watering etc. Also, respondents 1 and 3 mention the trucks that supply stores in the Langestraat and Krommestraat. When it comes to plans and initiative of greening these streets, the height and width of the trucks should be taken into consideration. All residents emphasize the challenges in implementing greening projects, partly due to limited budgets and bureaucratic processes.

Negative effects of greening

No major negative effects of greening are indicated by the residents. All residents stress the importance of maintenance of the green innovations.

Expert citizen initiatives

This expert gave his perspectives on the variety of events and citizen-driven projects that have influenced Amersfoort's transition to sustainability and community involvement.

A turning point for the Soesterkwartier's identity and drive for invention was their opposition to the demolition of a wagon workshop. The economic crisis put a stop to development efforts despite NS (Dutch Railways) early plans to suspend operations, turning protesters into important players in the area's destiny. A number of sustainable initiatives that were motivated by the community's dedication to environmental care were made possible by this resistance. Four working groups were

formed with the objectives of integrating green aspects, integrating sustainable energy, insulating collectively, and promoting sustainable mobility. Supported by a 2007/2008 Science Shop research, these efforts produced 15 projects, 12 of which had positive results. results, such as the creation of Ecotown, a model community for sustainable living.

The neighborhood experienced the effective installation of wadis, solar panels, and green belts despite obstacles like the arrival of windmills, which were maintained by local cooperation and sporadic governmental support. Nevertheless, there were challenges in this relationship as well, such as varying degrees of cooperation and obstacles from the law that hindered advancement.

Residents of Amersfoort, especially in certain of the city's neighborhoods, had a strong desire to address heat-related problems with vegetation. This was demonstrated by programs like Rainproof Amersfoort and the Steenbreek movement, which sought to improve public areas with the help of locals. Effective community mobilization has some hurdles, with locally organized workshops proving to be the most successful approach. Regrettably, vandalism is becoming a bigger issue that hinders advancements since Corona.

Shoppers

2 shoppers of Amersfoort were interviewed because shoppers might present a different opinion and viewpoint than residents. The following text is a summary describing the most important and useful insights given, which give an idea on the viewpoints and interests of this stakeholder.

The shoppers indicate that they shop in the city centre due to either the physical shopping experience, including the possibility to see and try products, and the enjoyable atmosphere, the cozy terraces, and unique shops. The concern about the loss of interesting stores in recent years is mentioned. The shoppers appreciate the charm of the city centre but desires more visible greenery, especially in the Langestraat. The reasons mentioned for greening are aesthetic reasons as well as potential benefits such as better air quality.

"I like the idea of greening those streets, green is beautiful, it just makes me happy when there are quite a few plants. And I think trees are also good for air quality."

One shopper has experienced occasional crowdedness in the city centre, particularly on Saturdays. This is a reason for this shopper to avoid the city on Saturdays. While the shoppers both do not recall experiencing heat or water overloads last summer, they like the idea of greening the Langestraat and Krommestraat, emphasizing its positive impacts on temperature on hot day, biodiversity, and the city's appearance. Regarding biodiversity, the shoppers associate it with a healthy environment and considers it important for both the environment and human well-being.

"When an environment looks like it has rich biodiversity, it gives me a healthy feeling. It is important for the environment and for people themselves. So, I think it is important."

Mentioned ideas for innovations are more benches, more nature-inspired seating near water, and more public restrooms for a better shopping experience. The shoppers see no challenges to greening and envisions benefits like increased shade and a more attractive and pleasant atmosphere. Only some concerns about maintenance in the fall and winter are mentioned.

Appendix F – Extended results from interviews with OBA

The "Ondernemers Binnenstad Amersfoort (OBA)", is an association of entrepreneurs of the city centre of Amersfoort. This association works together with the municipality on projects to fulfil the needs of the local entrepreneurs and make Amersfoort a more attractive city.

Vision

The vison of the OBA (Ondernemers Binnenstad Amersfoort, n.d.-b) aims to focus on transforming the city centre from a place to shop into a place to be by creating diverse experiences and activities for visitors by improving the attractiveness of the city centre. Their goal is to make the city centre appealing to various demographics including visitors, residents, workers, and tourists. They aim to create a lively, accessible, and connected city centre with high quality facilities where more people can spend longer periods of time, aiming to improve the vitality and attractiveness of the city centre to serve as a central hub for whole Amersfoort.

Projects

In order to do so, the OBA has initiated multiple projects to make the city a place to be. Their plan for a car-free city centre (Ondernemers Binnenstad Amersfoort, n.d.-a) is created to reduce the traffic in the city centre in order to make it more liveable. There is also an initiative to make a zero-emission city centre by 2025 (Ondernemers Binnenstad Amersfoort, n.d.-c) to improve the health of their residents.

Interviews

In total 4 members of the OBA were interviewed. 1 city manager and 3 entrepreneurs in the city centre with their establishment located either next to the Langestraat or Krommestraat. The members indicated that the streets have an aesthetic appeal and that there is a nice atmosphere. Unfortunately, all of the interviewees indicated that there was a bike problem in these streets: "there are too many bikes parked, it looks very messy" - member 2.

The members of the OBA are especially focused on the perception of attractiveness of the two streets. For attractiveness, the members had a positive opinion especially on flowers which were mentioned in all of the interviews. As member 2 said: "I would like more flowers". Another aspect of attractiveness that got mentioned all the time during the interviews is the "stoning" of the streets which has a negative impact on attractiveness. Member 1: "It is too stoned" and member 3: "It is just a lot of stone". In their opinion, the streets are just completely made from stone and lack a form of variation.

Their opinion on green is fairly positive but not decisive and have various reaction on the idea of greening the streets. With half of the members indicating being very positive such as member 1: "Excellent and needed", and half of the members not against it but not enthusiastic such as member 4: "fine". Only 1 of the members realized and indicated the possible influence of greening on climate change, this was Member 1 who said: "Reduces heat stress and improves climate adaptation". Also, only member 3 is enthusiastic about biodiversity and incorporating in the streets: "Biodiversity is important to me, and I think that every little bit helps". But the rest of the respondents were less focused on this aspect or did not know what it meant: "as long as it is beautiful". None of the respondents have indicated significant problems with heat stress, flooding, or overcrowding member 2: "It can be crowded but that is not a problem".

Appendix G – Extended results from interviews with NGOs

There are multiple non-governmental organisations (NGOs) in Amersfoort that can contribute to the greening of the Langestraat and Krommestraat. Possible import NGOs can be identified as key stakeholders.

Potential key stakeholder

033Groen which is located and fully operating in Amersfoort has been identified as an NGO that is possible to be a key player in this and future projects. They are a not-for-profit organization which previous endeavours fits this project well. Previous projects being gardens in Isselt, Liendert, Plataan, and Graaf Engelbertpad on which volunteers are actively working to create, manage and expand the gardens (033GROEN, n.d.-a). Helping locals of Amersfoort with setting up their own community garden in Count Basielaan, Schrijnwerkerslaan, Dubbele Sleutels, and Het Middelpunt. In these projects they use a mixed approach of just doing by unofficially using land of the municipality without informing them but being tolerated and discussing with the municipality and companies to create professional initiatives (033GROEN, n.d.-c). 033GROEN also has a project running called "Groene Schoolpleinen" in which they help schools to make their schoolyards greener to increase the wellbeing of children (033GROEN, n.d.-b).

Previous achievements

Their portfolio of already remarkable and already successful small and medium initiatives indicates shows that they have a lot of expertise and experience in projects that involve greening. This combined with their location and activity in Amersfoort which is the target location of this project makes them a good possible partner to work with. Due to their established role, they can also be useful and effective to stimulate the plan to green the city centre of Amersfoort. In addition, they also have a large social community of volunteers to create, maintain, and expand green areas while knowing which actions to undertake for successful implementation.

Another potential partner is the NGO "Stichting Groen In Amersfoort (SGIA)" which has a big portfolio of resistance against projects that harm nature (Stichting Groen in Amersfoort, n.d.). They indicate that they stand up for 83.000 trees, 100 plants and protected animals, and 100% clean air in Amersfoort which can make them a valuable partner. Working with SGIA can be helpful to reduce potential opposition for plans of the city centre. As SGIA also has a big network of social contacts consisting of volunteers they contain a lot of untapped expertise and insights that other institutions can lack.

The idea of a partnership with these NGOs and their possible inputs during this and future projects have not been discussed.

Interview

1 Interview with a volunteer of 033GROEN has been performed, the results of the interview show that they have a positive opinion on the Langestraat and Krommestraat. The volunteer indicated that both streets are lively with good facilities, but that they do not have enough green (with no distinction being made between the 2 streets). The volunteer experienced mild levels of heat stress as there was not enough shade to hide from the sun. This volunteer also indicated that negative side effects of greening can be the constant maintenance, large amount of effort and time being spent on it, and bad performing / wilting plants which can be a nuisance and bring additional costs. The volunteer finds the connection with nature important and thinks that Amersfoort needs to be a city that more closely resembles nature.

Appendix H – Extended results excursion Alkmaar

Interview and own observations

Alkmaar is an old city that used to have paved streets with only a few trees and little open soil. Therefore, the municipality started looking at solutions to improve the business climate of the core shopping area. In June of 2021, these paved streets caused major floodings. This event made it clear to everyone that something needed to be done. They decided to introduce more greenery in the streets, since that would also contribute to draining rainwater and reducing heat stress.

Figure H.1 - Façade gardens in the Boterstraat.

Figure H.2 - Façade climbing green.

In order to start greening, the municipality hired B+B to investigate the possibilities. They created a toolbox with several options for greening. Someone was appointed to go from door to door and discuss with the shop owners what would be possible for greening in front of their building. This was done because you need the agreement and cooperation of the owner for greenery on or against the façade. The entrepreneurs are responsible for the maintenance of the greenery in front of their own building, since these were too many small tasks for the municipality. The entrepreneurs did receive a subsidy from the municipality for the first years (since those are the most important years for the plants to settle) and they would of course also get the benefit of having a livelier street.

In the process of matching greening solutions to locations, a few specific restrictions had to be taken into account. The public lighting, which is attached to the walls just like in Amersfoort, had to be avoided because climbing plants can really damage the cables going up to the lamps. They also added green to monumental buildings in Alkmaar, but they had to carefully consider whether they might need a root canvas/foil (worteldoek) to keep the roots from damaging the building, which soil to use that does not affect the foundation and what species of plant to use because certain climbing plants have climbing roots that can corrode the grout.

Figure H.3 - Open soil surfaces with plants (plantenvakken) in de Laat.

Figure H.4 - Terrace between the open soil in de Laat.

Next to the façade gardens in the smaller streets (Figure E.1 & Figure E.2), open soil surfaces with plants (plantenvakken) were implemented in the Laat (Figure E.3). They are placed on the northside of the street, with seating and terrasses in between (FigureE.4). This used to be the hottest part of the street on summer days, but now the canopies provide shade. To give the greenery and pedestrians more space, it is now also illegal to cycle on the Laat during shopping hours and loading and unloading has to be done at the beginning of the street. Visitors can now walk on the sides of the street, but the southside is still broad enough for emergency vehicles and garbage trucks to pass through (minimum of 3.5 metres).

To realise this, the sewer system was changed at the same time from a common sewer system to a separated sewer system with a drainage transport (DT) sewer, which both drains the overflow of rainwater to the canals and can also provide the plants with water from the canal during drought. The sewer pipes were also moved from the sides of the street to the middle and the street itself has a slight slope towards the middle in a V-shape, so the water automatically runs down to the middle.

Figure H.5 - Rotating chairs in de Laat.

Figure H.6 - Flower mats around a Linde, with bulbs starting to show in de Laat.

The Laat had a few linden trees to begin with that have roots very close to the surface, so it was difficult to get perennial plants to root well underneath these trees. That is why wildflower mats (from Flower your place) were placed here (Figure E.6). Some of the old trees have been removed or moved to another location, however lots of other trees were added as well.

At the beginning, the focus was on increasing the biodiversity and choosing endemic species. For the biodiversity, they also looked at what purpose certain plants could fulfil in the ecosystem: what insects do they support, and whether they are melliferous or host plants (dracht- of waardplanten). Van den Berk has a good catalogue with information about each tree and what it is useful for. Natuur & Milieu (2023) also has a black list of trees that are invasive species and a green list of trees that are beneficial to biodiversity. Later, the experienced showed that people might see endemic species as boring or even as weeds that should be removed. That is why they started planting flower bulbs that flower first after the winter, so public perception is already swayed in the direction of greenery being a beautiful and therefore valuable part of the street (P. van Duivenvoorde, personal communication, February 15, 2024).

Appendix I – Rejected innovations

- **Green pergolas:**
  - **Reason for rejection:** Green pergolas require too much space, where other innovations can achieve the same results.
- **Green façades:**
  - **Reason for rejection:** Green façades would completely cover the façade, which is not possible for monumental buildings and makes shop windows very small and ineffective.
- **Pocket park:**
  - **Reason for rejection:** Requires too much space, which is not available.
- **Fountains:**
  - **Reason for rejection:** Fountains cost a lot of water and energy and only solve the issue of heat stress. Greenery is far more versatile.
- **Shading devices:**
  - **Reason for rejection:** No added value to biodiversity, water management or air quality, just heat stress.
- **Green maintenance:**
  - **Reason for rejection:** Green maintenance would make the greenery look less orderly, which would reduce attractiveness and reduce the respect with which people treat the greenery.
- **Usage of material cycles:**
  - **Reason for rejection:** Recycling biomass would be sustainable, but the compost needs to be stored somewhere and that is not very attractive in a shopping street.
- **Permeable pavement:**
  - **Reason for rejection:** Because of the intensive use of the street throughout the week, the effectiveness would quickly be reduced.
- **Water squares:**
  - **Reason for rejection:** This would take up too much space.

Appendix J – Maps of available planting space Langestraat

Figure J.1 - The available space for the planting of trees considering a buffer of 2 meter around the cables and pipelines.

Figure J.2 - The available space for the planting of trees considering a buffer of 1 meter around the cables and pipelines.