Barriers and Enablers to Implementing Urban Trees as an Adaptation Strategy against Urban Heat - Case Study Leeuwarden

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Abstract

Trees as a Nature-based solution (NBS) have been shown to be an effective adaptation strategy against Urban Heat Island effect. The EU is increasingly using NBS to address the climate change impacts, but practical implementation on a municipality level has remained relatively unclear and slow. While previous studies have identified barriers and enablers, research on specific types of NBS, especially in smaller cities, is limited. The city of Leeuwarden, in the Netherlands, faces challenges in adapting to extreme heat and therefore plans to use greening strategies. This paper aims to explore, what are the barriers and enablers to uptake and implement urban trees as an adaptation strategy to urban heating in the case of Leeuwarden. The research methodology involves reviewing previous literature on the topic, analysing relevant EU policies and conducting semi-structured key informant interviews. The main barriers experienced in Leeuwarden were the limited space, inadequate integration into infrastructure planning, lack of collaboration and finance, and environmental challenges. Enablers were identified to be political will and citizen engagement, knowledge, strategies, collaboration and experiments. EU policies were considered to be encouraging. The results highlight the importance of knowledge sharing, co-design and collaboration in order to implement trees in a manner that is feasible on a long term. Future research could focus on comparative analysis between local en EU policies.

Keywords: Urban trees, climate adaptation, Urban heat Island effect, Nature-based solutions, Green Infrastructure, Policy-making, Barriers, Enablers

1. Introduction

Nature-based solutions (NBS) and green infrastructure (GI) have gained attention in recent years as effective approaches to address socio-environmental challenges in urban areas (Kabisch et al., 2022; Sturiale et al., 2019). Trees, as a specific form of NBS and GI, have been shown to be an effective adaptation strategy against Urban Heat Island effect (Iungman et al., 2023; Schwaab et al., 2021; Wang et al., 2019; Bona et al., 2022; Cortinovis et al., 2022). Urban Heat Island phenomena, caused by climate change, is one of the most well-known effects of urban development and is accelerated by climate change (Sturiale & Scuderi, 2019). Even though NBS and GI are becoming more popular in climate mitigation and adaptation, and the positive effects of urban trees are widely recognized, the practical implementation is still unclear, and municipal progress is still slow (Back & Collins, 2022; Sowińska-Świerkosz & García, 2022). Previous studies have identified barriers and enablers that shape the NBS and GI implementation on a municipal level. (Kabisch et al., 2022; Sarabi et al., 2019) However, research regarding specific types of NBS and GI remains relatively limited, especially regarding smaller cities (Sarabi et al., 2019; Back & Collins, 2022).

Much like other cities in Europe, Leeuwarden is experiencing increasingly extreme heat and is facing difficulties in adapting (Ascione et al., 2022; Kennedy, 2022; UNECE, 2021). The municipality of Leeuwarden is adapting to the heat stress by planning to make the city greener in the near future, where trees play a central role (Kennedy, 2022). Therefore this paper aims to explore what are the barriers and enablers of implementing urban trees as an adaptation strategy to urban heating in Leeuwarden.

Urbanisation is expected to increase across the globe. It is anticipated that by 2050, at least two-thirds of humanity will be living in cities (Alves et al., 2020; Vaňo et al., 2021; UN DESA, 2018). As a result, urban areas will increasingly encounter various sustainable development issues (Alves et al., 2020). These include adapting to climate change, addressing socioeconomic inequality, and tackling the severe environmental degradation that requires nature conservation (Vaňo et al., 2021). One of the most well-known effects of urban development is the Urban Heat Island (UHI) effect (Sturiale & Scuderi, 2019). To address the impact of climate change, including the UHI issue, the EU has had great ambition to establish Europe as a global leader in NBS in terms of implementation and

promotion (Calliari et al., 2022). The EU aims to achieve this through scientific research creating knowledge and theories, encouraging innovation of novel strategies and best practices as well as globally promoting communication and cooperation (Davies et al., 2021).

NBS refers to the use of natural processes and ecosystems to address societal challenges, while GI is a network of natural and semi-natural areas that provide multiple ecological, social, and economic benefits to urban and rural areas. (Escobedo et al., 2019). Trees are one form of NBS and can also work as a GI (UNECE, 2021). Trees among other NBS and GI are multifunctional as they have multiple environmental and socio-economic benefits in addition to cooling the air, such as better air quality and nicer atmosphere (Sturiale et al.,2019; van der Jagt et al.,2023).

According to Muñoz Sanz et al.,(2022) effective approaches to implement new urban trees and forests successfully are not well understood yet. Back, & Collins (2022) describe that municipal progress on GI is still slow, and its full potential has not been unleashed despite increased acknowledgment of the advantages of GI and a growing commitment to climate change adaptation. Therefore Back, & Collins (2022) argue it is crucial to understand how municipalities approach and use GI, what they hope to accomplish with this strategy, and what barriers slow down the implementation. Current research has been largely focused on bigger cities and studies of NBS and GI practice in smaller cities are still relatively uncommon (Back & Collins, 2022) However many smaller cities are active in implementing different NBS and GI, including trees (Back & Collins, 2022).

Recent research shows that in Europe, trees mitigating UHI are most effective in the Mid-European region, where also the Netherlands is located, compared to E. g. Mediterranean region (Schwaab et al.,2021). Because Leeuwaarden, Netherlands is a small city which is located in the Mid-European region (*Leeuwarden in Cijfers,* n.d & Schwaab et al., 2021) it presents an interesting case study. Leeuwarden is particularly vulnerable to the effects of climate change because of its geographical location (Cities Northern Netherlands, n.d.). Therefore, by 2035, Leeuwarden aspires to be climate-adaptive in order to be ready for the rising dangers of heat, flooding and drought (Cities Northern Netherlands, n.d.). To tackle the heat, the city wants to create a 10% increase in canopy cover over warm, large and paved surfaces (Klimaatadaptatie; n.d.). Additionally, Leeuwarden plans to construct shadow islands near areas where people gather together and areas where vulnerable

people reside, E. g. Healthcare institutions and Schools (Klimaatadaptatie; n.d.). To become climate adaptive, the city is working together with residents, companies and different stakeholders (Klimaatadaptatie; n.d.) In 2022 the city of Leeuwarden had a tree project Bosk in, during 100 days 1200 movable trees "walked" through the city centre of leeuwarden. (*Bosk – Groen Leeft in Leeuwarden*, n.d. ;Gemeente Leeuwarden, 2023). Later these trees were planted permanently around the city. (Gemeente Leeuwarden, 2023).

To answer the research question, *what are the barriers and enablers to uptake and implement urban trees as an adaptation strategy to urban heating in Leeuwarden*, a mixed research method of narrative literature review, policy analysis and key informant interviews were used. The first section of the literature review will discuss the UHI. This is followed by an explanation of how urban trees can work as an adaptation strategy to UHI, by exploring the conceptualisation of Nature-based Solutions (NBS) and Green infrastructure (GI). Four relevant EU policies, addressing the NBS and GI are analysed to gain insights and reflect on the effectiveness and adaptability of these policies in a local context. These are namely the EU Biodiversity Strategy for 2030, EU Forest Strategy, EU Strategy on Adaptation to Climate Change, EU Urban Agenda. Previous research is reviewed about the experienced barriers and enablers to uptake and implement urban trees, NBS or GI in general on municipality level. Finally Insights were gained through literature review and interviewing civil servants and the private sector. The following paragraphs will explain the methodology for the literature review, policy analysis and the interviews.

2. Methods

Literature review and policy analysis methodology

Recent literature about the UHI effect and the NSB, GI and Urban trees was gathered between January and May 2023. The Policy analysis focuses on EU policies that address NBS and GI in urban areas, including trees. The search was limited to papers published between 2015 and 2023, placing focus on the most recent sources. Both peer reviewed and grey literature was reviewed for this paper.

Literature was gathered using SmartCat Library search engine, Google Scholar, Google and websites europa.eu, eur-lex.europa.eu, futurium.ec.europa.ey and unece.org. Research rabbit tool was used to identify connections between the research papers and authors as well explore further sources (*Research Rabbit*).

Interview selection criteria and data analysis

Semi-structured, qualitative key informant interviews were conducted with 3 individuals with experience related to urban trees and greenery, urban planning and/or climate adaptation in Leeuwarden. Total of 17 individuals were contacted to participate in an interview. The contacted persons were chosen based on purposive sampling and partly using a snowball sampling. Total of three individuals accepted to participate in an interview. Purposive sampling is commonly used in qualitative studies to choose participants based on the qualities they have (Back & Collins, 2022; Etikan et al., 2015). It is particularly valuable when randomization techniques are not feasible or when resources and time are limited for the research. In purposive sampling, the participants are chosen based on the goal of the study with the intention that each participant will contribute rich and unique information that is valuable to the study (Etikan et al., 2015). Snowball sampling is commonly used to find individuals for a study who possess specific characteristics or expertise (Hennink et al., 2022). The process of snowball sampling entails requesting a current participant of the study or a key informant if they are aware of any other individuals who match the study's criteria, and requesting them to provide a referral to the researcher (Hennink et al., 2022). Participation in this research was completely voluntary and anonymous, the data was kept private according to the General Data Protection Regulation (GDPR) rules of the University of Groningen. The detailed ethical considerations, information sheet and consent form are provided in the appendix A, B and C.

Interview questions about the experienced barriers and opportunities were formed by reviewing related research and previously used topics or identified themes. As the results are key informant interviews, they provide insight but are not generalizable to the population (Etikan et al., 2015). The interview data was analysed with qualitative methods. This is done by examining whether survey respondents used similar topics and/or phrases and developing codes accordingly (Attride-Stirling

2001). To identify the main themes, the transcribed interviews were coded and analysed with both “constructed code” and "in vivo" approaches, as some of the codes were based on participants' wordings and some were created by the researcher using Academic terms (Khandkar, 2009).

3. Literature Review

Urban Heat Island effect

Regarding human health and environmental quality, the Urban Heat Island (UHI) effect is one of the major consequences of urbanisation, and climate change is predicted to significantly aggravate the effect (Sturiale & Scuderi, 2019). UHI is defined as a specific urban or metropolitan climate where the temperature is significantly higher in the densely populated built environment compared to the surrounding rural and natural area (Marando et al. 2019; Marando et al., 2022; Thanvisitthpon, 2023). The UHI phenomenon results from anthropogenic changes to the environment; particularly the change of natural land cover to infrastructure that absorbs and stores heat, such as buildings, pavements and impermeable surfaces (Marando et al., 2022; Thanvisitthpon, 2023). The process of evapotranspiration and the release of latent heat are slowed down by the reduced amount of vegetation (Salmanian & Bayat, 2023). Main negative effects of UHIs are increased energy use, higher emissions of greenhouse gases and air pollutants, decreased human health and comfort, and decrease in water quality (Thanvisitthpon, 2023). For those who live in cities, the Urban Heat Island (UHI) is one of the most dangerous environmental hazards (Marando et al., 2022). According to Ascione et al., (2022) As a result of climate change, heat-related mortality is on the rise and Europe has one the fastest growing trends as the percentage of excess deaths caused by high temperatures increased from 1.99 to 2.63% between 2000 and 2019 (Ascione et. al, 2022). As urbanisation only increases and climate change is worsening the consequences, the need for cities to implement adaptation strategies is becoming more urgent (Ascione et. al, 2022; Marando et al., 2022). Green strategies have received increasing interest as they have been shown to play a significant role in cities' adaptation to climate change, such as the UHI (Iungman et al.,2023; Marando et al., 2022)

Trees as a Nature Based Solutions and Green Infrastructure

Trees are considered to be an effective form of adaptation strategy for UHI effect (Calliari et al., 2022; Iungman et al., 2023). In literature trees are often referred to as Nature-based solutions (NBS) or Green infrastructure (GI), that are the broader concepts of urban greenery (Escobedo et al., 2019; Sowińska-Świerkosz & García, 2022). These abbreviations are often used in policy making and urban planning (Escobedo et al., 2019. During the past few decades, a variety of metaphors about approaches and concepts fostering multidisciplinary information on urban ecosystems have evolved, including the NBS and GI (Escobedo et al., 2019). The conseptualisalisation of Urban trees, NBS and GI is explained in this section, to understand the interconnectedness of the concepts and their use in the reviewed literature and policies.

Nature-based solutions (NBS) are an unifying umbrella term for various multifunctional approaches that use both entirely natural approaches and a combination of natural and technological ones to address multiple challenges (Castellari et al., 2021; Calfapietra, & Cherubini, 2019; Kabisch et al.,2022 Raymond et al., 2017). Urban trees, green facades and roofs, and water filtration and storage systems are few examples of NBS (Calfapietra, & Cherubini, 2019). Escobedo et al., (2019) defines the most recent NBS paradigm as a development of the previous metaphors Urban Forest (UF), ecosystem services (ES), green infrastructure (GI), toward a more transdisciplinary approach that offers practical solutions. NBS, GI and ES all have similar roots in UF. GI focuses on spatial patterns and connectivity of the natural network, while ES performs many natural functions that can be beneficial for nature and humans. (Escobedo et al., 2019). As a result, the emergence of NBS shows that the scope has recently expanded to include applications to address a variety of emerging and escalating urban environmental, socio-political and ecological concerns (Escobedo et al., 2019). However, a recent study by Sowińska-Świerkosz & García, (2022) sees that NBS as a concept and its practical application are still unclear. They explain that the NBS concept's emergence from the fusion of numerous scientific domains has resulted in ambiguity of the concept. Therefore Sowińska-Świerkosz & García (2022) have clarified the concept of NBS by identifying their key characteristics and creating criteria which helps to exclude specific approaches from the category of NBS. According to the Sowińska-Świerkosz & García (2022) definition, the NBS concept excludes

those solutions that do not increase biodiversity or the ones that do not explicitly and measurably define and monitor conservation goals for biodiversity. The existence of trees and other plants in the urban area works as a socio-ecological system that is resilient to climate change (UNECE, 2021).

The European Commission has defined NBS as "solutions that are inspired and supported by nature" (Cohen-Shacham et al., 2019; European Commission, 2023a). NBS are interventions that bring components and processes from nature to cities, landscapes and seascapes. These interventions are locally adapted to restore, link, and maintain natural processes (Herzog et al., 2022; European Commission, 2023a). NBS must enhance biodiversity and facilitate the provision of a number of ecosystem services (European Commission, 2023a). GI is defined by the European Commission as a network of natural and semi-natural areas that are strategically planned and managed to ecosystem services such as counteract the UHI effect (Castellari et al., 2021).

One of the main advantages of NBS and GI is their multifunctionality. They can provide various benefits and ecosystem services at once in the same spatial area (Nordh & Olafsson, 2021; Herzog et al., 2022). This makes NBS cost and resource efficient and provide benefits for the environment, society, and economy, as well as create resilience (Cohen-Shacham et al., 2019; European Commission, 2023a). They are also seen as an innovative way in the green economy to generate jobs and growth (Escobedo et al., 2019). Additionally, International organisations like the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services (IPBES) and Intergovernmental Panel on Climate Change (IPCC) have recognized the importance of conserving and re-introducing green spaces into urban areas as an NBS to manage climate change, biodiversity and water crises. (de Oliveira, et al.,2022; Herzog et al., 2022). There is not one specific discipline or science for NBS and GI as they are so multifunctional (Sturiale, & Scuderi, 2019; Sowińska-Świerkosz & García, 2022).

There has been an increase in efforts in promotion and research of urban trees and their numerous benefits to address difficulties impacting urban regions, especially in regards to protecting and growing the urban tree canopy in the context of urban climate adaptation (Escobedo et al., 2019; Muñoz Sanz et al., 2022). Like other NBS and GI, trees are multifunctional, they not only reduce the heat but also reduce carbon dioxide emissions, improve air quality, enhance public health and quality

of life (Muñoz Sanz et al., 2022). Urban forestry enhances evapotranspiration, shadow production, and the amount of sunlight that reaches the canopy (Salmanian & Bayat, 2023). Adding more trees along streets and other areas of the public right of way is one of the most crucial things that can be done to create more green spaces in an urban area (McDonald et al.,2023). According to Cortinovis and colleagues (2022) planting trees in public areas and alongside the streets is a highly efficient approach to provide various benefits in a balanced and distributed manner. Cortinovis and colleagues (2022) argue that the most effective single technique for achieving numerous benefits. As a comparison, green roofs have little impact on greenness and only a limited ability to reduce heat when compared to urban forestry. Furthermore, street trees reduce runoff more efficiently and any type of urban trees has bigger carbon storage (Cortinovis et al., 2022)

Research has shown that the greatest impact on heat mitigation is achieved with urban parks and planting trees along the streets (Bona et al., 2022; Cortinovis et al., 2022). Planting trees is crucial for urban tree canopy cover because it can overhang concrete surfaces and pavements, clearly illustrating how human development and green places share space (McDonald et al.,2023). According to Schwaab et al., (2021), Urban green spaces that do not include trees are overall less effective at lowering land surface temperatures (LST), and their cooling effect is around 2-4 times lower than cooling brought on by urban trees. Using trees to shade these impervious surfaces has a significant impact on reducing UHI and helps to absorb stormwater (McDonald et al.,2023).

Study by Iungman et al., (2023) studied 93 cities in Europe and indicated that one third of the UHI related deaths could be prevented by implementing 30% tree cover in the urban areas. Cortinovis et al., (2022) Explains that when implementing NBS, the availability of space plays a critical role. Especially modifying the existing built infrastructure, and densely populated areas the possibilities are limited. However, at the same time these areas are the most vulnerable urban areas to climate change (Cortinovis et al., 2022). The study by Cortinovis et al., (2022) showed that the most space-effective way to provide numerous benefits for the city is to plant trees, as they provide the most benefits compared to the space they need. However the benefits that trees can provide for a city vary a lot depending on the area. Therefore the effects of trees on for example shading and amount of wind and humidity need to be considered (Schwaab et al., 2021). Research by Schwaab et al., (2021) found that

Land surface temperature (LST) for urban trees compared to continuous urban fabric is lower in Central European regions compared to Southern European regions. This suggests that trees have higher cooling potential in central Europe compared to southern Europe (Schwaab et al., 2021). Another study shows evidence that heat waves have a greater impact on cooler cities than on warmer ones. Hence, it appears that cooler towns are more vulnerable to heat waves, whereas warmer cities may be better equipped to adapt (Ward et al., 2016). While NBS and GI are considered as effective approaches for tackling and adapting to increasing heat, urban trees in particular stand out as the most efficient solutions. The concepts NBS GI are both used in policy making. When trees are not mentioned explicitly in EU policies, they fall under the concepts of NBS and GI. For the purpose of this paper trees are considered as both NBS and GI, as both of them were used in the reviewed literature and policies.

Policy analysis: EU policies

Multiple EU strategies rely on NBS in order to enhance climate resiliency (Calliari et al., 2022). Policies discussed in this paper are the EU Biodiversity Strategy for 2030, EU Strategy on Adaptation to Climate Change, EU Forest Strategy as well as EU Urban agenda. These policies address NBS and GI in urban areas, including trees. The Biodiversity Strategy, the Forest Strategy and the Strategy on Adaptation to Climate Change, are building blocks of the EU Green Deal, playing an important part in climate change adaptation (Varbova, 2022). As a response to the complex challenges in urban areas, like UHI, the European decision-makers and sources of research funding have quickly adopted the NBS and GI metaphors into the policy making (Escobedo et al.,2019; Vaňo et al.,2021). They are used as a solution-orientated planning strategy that balances climate adaptation, urbanisation and conservation of nature (Vaňo et al.,2021).

Despite the growing use of NBS and GI in the policies, the level of integration within current policy frameworks is still limited (Davies et al., 2021). As Calliari and colleagues (2022) wrote, the previous analyses of the EU policy framework show that the majority of the instruments used to implement NBS and related concepts are non-binding (Calliari et al., 2022). The majority of policies are based on voluntary activity and participation (Calliari et al., 2022). Furthermore the policies

frequently lack quantifiable and measurable targets for NBS deployment and quality (Calliari et al., 2022). Another factor that seriously hinders the implementation is the inconsistency between local, regional, national, and international policies and regulations (Davies et al., 2021). Calliari et al., (2022) brings up the challenge that the EU policy framework must be adaptable enough to support Member State sovereignty and, consequently, the modification of actionable policies to local situations, but it also needs to make sure that its objectives and goals will be achieved.

EU Biodiversity Strategy for 2030

The EU's Biodiversity Strategy for 2030 is one of the policies that clearly recognizes the importance of urban trees (European Environment Agency. (n.d.). The EU created the biodiversity strategy for 2030, to protect nature and stop ecosystems from degrading (European Commission, 2023b). The emphasis is on the connectivity between the biodiversity crisis and the climate crisis and the need for coordinated action, both of which are central to the greening cities issue (Varbova, 2022). EU Biodiversity Strategy for 2030 is a long-term comprehensive and ambitious plan that aims to improve the management, planning, and preservation of urban green spaces (UNECE, 2021; European Commission, 2023b). The strategy highlights that by planting trees, cities can cool urban areas and reduce the effects of natural disasters (European Commission, 2020). The Biodiversity Strategy for example mandates that cities with more than 20,000 people establish urban greening plans, and includes steps to promote biodiverse and accessible urban green spaces, like parks, gardens and street trees (European Commission, 2020; European Environment Agency, n.d.). Key element of this Strategy is the new EU Nature Restoration Law proposed in June 2022 (European Commission, 2022a). This Law includes legally binding targets for the member states, especially concerning those ecosystems that have the greatest potential in preventing and reducing the effects of natural disasters (Varbova, 2022). Some of these targets address directly urban trees. I.e. all cities the urban tree canopy cover has no net loss by 2030, compared to 2021. Additionally the tree canopy cover needs to increase by at least 10% by 2050 in every city and all towns and suburbs. (Article 6) (European Commission, 2022b). In the strategy the urban greening responsibilities is allocated specifically to the municipality level (Muñoz Sanz et al., 2022) Therefore, mainly the municipal urban planning is primarily faced

with difficulties regarding adapting processes and strategies to mainstream tree planting and urban greening (Muñoz Sanz et al., 2022)

EU Forest Strategy

Urban forestry is one focus area of the EU Forest strategy for 2030 that was published in 2021. The EU Forest Strategy is rooted in the European Green Deal and the EU 2030 Biodiversity Strategy (European Commission, 2021). The multifunctionality and essential role of trees are acknowledged in achieving a sustainable economy while ensuring that all ecosystems are properly protected, restored, and made resilient (European Commission, 2021). The strategy promotes the extension of forest areas and includes a roadmap to add 3 billion new trees by 2030 (European Commission, 2020; European Environment Agency. n.d.; UNECE, 2021). The Strategy states that urban areas present a great potential for extending tree coverage in the EU, by sustainably and actively planting trees on public and private property (European Commission, 2021). The new trees would be planted respecting fully the ecological principles; right species should be selected and placed with the right purpose to a right place that is adequate for the tree to grow (European Commission, 2021).

EU Strategy on Adaptation to Climate Change

The European Strategy on Adaptation to Climate Change is an example of EU policy initiatives with strong embedded NBS components as an effective and affordable strategy of supporting ecosystem-based disaster risk reduction and adaptation to climate change as a response to the increasing natural hazards like heat waves (Davies et al., 2021). This strategy views NBS as a "noregret" adaptation solution, as they provide positive impacts on social, environmental and economical aspects (European Environment Agency, n.d.). Thus these investments have positive outcomes in society, whether they work well or not in terms of climate adaptation (European Environment Agency, n.d.). Furthermore the strategy emphasises the need for more research, more funding, and the creation of effective ecosystem management strategies regarding NBS (Calliari,

2021). However it is lacking clear requirements for action such as creation of national adaptation strategy that would integrate NBS for Change Adaptation /Disaster risk reduction (Calliari, 2021)

EU Urban agenda

The Urban Agenda for the (UAEU) places a strong emphasis on using nature-based solutions (NBS) and green infrastructure (GI) to solve urban problems (Calliari et al., 2022). The (UAEU) was launched in 2016. It represents a multi-level approach to working that encourages collaboration between cities, Member States, the European Commission, as well as other stakeholders in order to promote innovation, growth, and liveability and recognize and address social concerns (European Commission, n.d.). The UAEU focuses on three pillars of EU policy making and implementation: Better regulation, better funding and better knowledge (European Commission, n.d; Varbova, 2022). In the UAEU, NBS and GI are specifically mentioned as essential strategies for improving the sustainability and livability of urban environments, particularly in the Action plans for “Climate Adaptation Partnership” And “Sustainable Use of Land and Nature-Based Solutions Partnership" (Calliari et al., 2022; European Commission, 2018a; European Commission, 2018b). However these action plans are stated to be non binding (European Commission, 2018a; European Commission, 2018b). The UAEU is organised in a way that it encourages Member States to voluntarily join partnerships to undertake research and carry out the created Action Plans and choose which aspects they wish to focus on (Calliari et al., 2022). As these policies rely on member states' initiative and voluntary pledges, they fail to establish criteria and standards or supportive measures (Calliari et al., 2022).

Barriers and Enablers of implementing NBS and GI on a municipality level.

Barriers and challenges

Different barriers and challenges for uptaking and implementing NSB and GI on a municipality level have been identified by research (Back, & Collins 2022; Kabisch et al., 2022; Muñoz Sanz et al., 2022; Sarabi et al., 2019). According to Sarabi and colleagues (2019) uncertainty

about the implementation process and the benefits of NBS was the most commonly noted barrier, followed by insufficient financial resources. They also explained that a lack of space especially in an inner city is a barrier NBS solutions take up more space than conventional grey infrastructure, furthermore many NBS need time to provide the benefits, and therefore the time frame is being perceived as a barrier (Sarabi et al.,2019). Other barriers were connected to path dependency in decision-making, institutional fragmentation, and inadequate legislation.

Kabish and colleagues (2022) argue that applying NBS in urban areas comes with particular challenges. They identified five main difficulties cities face. The complex system of cities is interdependent and multidimensional. Therefore there can be conflict between the green areas and other infrastructure development like commercial, residential, and transport infrastructure (Kabisch et al., 2022). Urban biodiversity presents challenges as it is different from the regional biodiversity. Water and soil regimes are easily impacted by human activities. Urban biodiversity is vulnerable as they are small and isolated, but simultaneously they also can be a biodiversity hotspot for species that do not survive in the modern agricultural rural areas (Kabisch et al., 2022). Another challenge cities face is to prevent unintended social consequences. NBS interventions need to include different actors and stakeholders to avoid inequalities and for example gentrification (Kabisch et al., 2022). Path dependency refers to a challenge where the existing paradigms and practices that favour grey infrastructure persist still in the planning process. (Kabisch et al., 2022). Misconceptions are still a present challenge as there are still perceptions that urban areas exist in isolation from nature rather than part of it. This type of perception highlights technological development over nature and ecological innovations (Kabisch et al., 2022).

One key barrier is that NBS is not mainstreamed in urban planning and development (van der Jagt et al.,2023; Adams et al., 2023). Mainstream refers to the way that urban development “normally” happens (Dorst et al.,2022). In order to effectively realise NBS mainstreaming for cities, and replace unsustainable practices, NBS mainstreaming needs to be framed through governance implementation and urban planning. This way the NBS could be the normal course in practice and not just a novelty (Adams et al., 2023). However Dorst and colleagues (2022) have identified that there are seven main structural barriers to the mainstreaming of urban NBS. These are the limited

collaborative governance, challenges in data knowledge and awareness, private sectors low participation, competition with other infrastructure, inadequate policies, implementation and enforcement, limited resources, low engagement from citizens (Dorst et al., 2022). Furthermore the mainstreaming of NBS and monitoring their implementation is also missing in the EU requirements (Calliari et al., 2022).

Back, & Collins (2022) researched the perception of importance, top priorities, and challenges that were experienced when establishing GI projects in smaller cities northwest Europe. The results of the study indicated that smaller cities have different priorities in GI delivery compared to bigger cities, and this might limit the transfer of GI best practices from larger cities. Smaller cities seemed to value and prioritise short term benefits such as aesthetics and liveability for the citizens are often connected to the electoral cycles. Long term objectives were prioritised less, like economical concerns or climate change. Identified obstacles were connected to collaboration and capacity. Lack of leadership and the prioritisation showed as a difficulty to cooperation and fragmented city organisation. Furthermore Inadequate corporate-level leadership was perceived as the reason why cooperation within the city organisation was found to be more difficult than with outside organisations. Capacity was another significant problem, and the findings show a lack of resources as well as staff time and expertise (Back, & Collins, 2022). Sarabi and colleagues (2019) suggested that more research should be done regarding the barriers and opportunities of different specific types of NBS. Muñoz Sanz and colleagues (2022) research barriers specifically concerning implementation of trees. They found that the main challenges were related to insufficient coordination and collaboration amongst municipal departments. Additionally they identified that there is lack of information, continuity through political cycles and adequate leadership and finance (Muñoz Sanz et al., 2022).

Enablers and opportunities

The governance structure that supports the NBS policy process is crucial to the achievement of uptake and implementation of NBS in urban environments (Martin et al.,2021). Research by Sarabi and colleagues (2019) identified the key enablers for the implementing NBS in urban environments. The most frequent enabler appeared to be the collaboration and partnerships between different actors

in all vertical and horizontal levels in public and private sectors. Also according to Martin and colleagues (2021) one of the key governance enablers is indeed the polycentric approach in governance. This entails new public administration structures that include various institutional scales and/or sectors (Martin et al., 2021).

These opportunities in collaboration are connected to the multifunctionality of NBS, as many actors can benefit from the NBS, they can unite their efforts to materialise the plans, thereby facilitating aspects such as financing (Sarabi et al., 2019).

Adequate planning and design enables uptake and implementation of NBS (Sarabi et al., 2019). Especially co-design that includes innovative participatory planning with different stakeholders has been argued to be important (Sarabi et al., 2019; Martin et al., 2022). Knowledge is an important driver for mainstreaming NBS as it shapes our understanding of the environment and consequently translates into policy and actions (Adams et al., 2023). The knowledge driver encompasses the integration of knowledge to the institutions, projects and policy, co-producing knowledge with experts, researchers and policymakers and also the distribution of the knowledge across different sectors and disciplines (Adams et al., 2023)

Monetary Instruments and financial incentives are also important enablers. These include those that are targeted to implementation and monitoring on a community level (Sarabi et al., 2019; Martin et al., 2022). Other enablers identified by Sarabi and colleagues (2019) were sufficient monitoring, exchange of knowledge, plans and laws, education and training, combining NBS with grey infrastructure and open experimentation and innovation.

4. Results and Discussion

This section will present and discuss the result from the key informant interviews to provide insights on the current experienced barriers and enablers for the implementation of urban trees in Leeuwarden. As this research was focused specifically on trees as a type of NBS, it gives an understanding of the local level practical side of climate adaptation strategies and urban greening

Trees present a great opportunity to reduce the UHI and increase the overall livability of cities. However the successful implementation is highly dependent on clear understanding of practical

aspects and long term implications (Sarabi et al., 2019; Martin et al.,2021; Adams et al., 2023). Based on the interviews and literature, it seems that in recent years there has been an increasing amount of effort in implementing trees as an NBS in Leeuwarden. However The interviews indicated that some barriers still hinder the implementation.

The biggest challenges regarding implementing trees in the urban area In Leeuwarden, was indicated to be the lack of space underground and the lack of integrating NBS in general to all infrastructure projects and decision making as well as lack of communication between different actors. Other barriers were experienced to the finance, and environmental conditions such as diseases and heavy traffic. Regardless of the experienced barriers there were a number of enablers and opportunities to overcome these barriers. One of the biggest enablers was indicated to be an overall positive political mindset among citizens and decision-makers. Even though there are still challenges in terms of feasible implementation, the interviewees indicated that there seem to be increasingly realistic approaches, such as the greening strategy. The Lack of collaboration and finance was experienced to be barriers but also seen as opportunities as there has been an increase in both lately. Another significant enabler was Bosk 'walking' forest" event as an experiment which enhanced the people's mindset and inspired more permanent projects and facilitated more collaboration. The role of the EU was perceived generally encouraging and positive but the perception of its prevalence and importance varied. This section will first present and discuss the experienced barriers and challenges which is followed by the experienced enablers and opportunities. Finally the interconnectedness of these barriers and enablers is discussed.

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Barriers and challenges for the uptake and implementation of trees

Densely built infrastructure and lack of space

Lack of space was experienced to be the most pressing barrier to uptake and implement trees in the city centre of Leeuwarden by two interviewees. They explained that in the densely built and

populated city centre, it is difficult to find enough space underground for the trees. At the moment there are many pipes and cables underground and even more is being built on top of the existing infrastructure. In addition the high groundwater level adds challenges, reported one of the interviewees. For these reasons the interviewees experienced the space to be often too small for the tree to grow old or can even prevent planting a tree completely. Two interviewees reported that currently the trees are not growing well and therefore trees need to be removed after 10-15 years, or earlier as they get sick or die. One interviewee perceived that this is a result of the current plans that often include too many trees, in too small an area and therefore the trees cannot grow. If the tree is planted in an adequate manner to a place where it has enough room and soil under the ground, it can grow old and provide ecosystem services for a longer period of time, reported one of the interviewees. The bigger the tree is and the older it gets, the wider variety of ecosystem services it can provide. Regarding shading from the sun and regulating the temperature, a few bigger trees would be better and many small ones, according to one participant. The same applies also to other services that trees can provide, such as better mental well being of the citizens. Two of the interviewees highlight that it is more important to plant trees in the right way, so that they remain healthy and grow old, rather than planting many trees that will not survive long. It was indicated that there should be better focus on the quality of the trees rather than the quantity. Another factor making it difficult to find place was indicated by one participant was the many differing opinions of where trees should be placed (E. g.. too much shading or falling flowers to the cars)

These results are in line with the reviewed literature, as according to Cortinovis and colleagues (2022) the spaces in the urban area that are usually the most vulnerable for climate change, are also the most densely built and populated, thus there are limited possibilities to modify the infrastructure. In accordance with the present results, also previous studies have found that the lack of space was indicated to be a barrier, especially as the complexity of the city infrastructure results in competition and conflict between trees and grey infrastructure such as residential buildings and transportation infrastructure (Dorst et al, 2022; Kabisch et al., 2022; Sarabi et al.,2019).

Lack of integration and collaboration

Another significant barrier mentioned was the lack of collaboration and communication between the practical side of tree planting and other infrastructure projects, the general planning and decision makers. One interviewee perceived that unrealistic plans to plant trees are being proposed by the planners and decision makers as they do not understand what their decisions actually mean. This was connected to cause the trees to be planted inadequately and increased the cost of planting.

Even though the bottom up approach indicated to be taking place to a certain extent, it remains to be a challenge as the plans are often not carried out as planned. One interviewee gave an example that sometimes the tree experts are asked during development processes, what should be taken into account regarding the placement of e.g. pipes and cables or what is the status of the existing trees. However, often the practical construction of the new or renewed infrastructure ends up not executing the plan accordingly, thus the enforcement fails. Consequently the pipes and cables are built everywhere and there is actually no place for trees.

One interviewee explained that the trees and greenery is not integrated enough to most infrastructure projects and planning processes, but rather added in the end phase “on top” of the other plans. Problem was raised that some projects can have significant collateral damage, as the long term impacts for trees are not evaluated in the planning process. An example brought up was an EU funded infrastructure plan that included many small trees along the road. In that project area there are too many trees that do not have enough space to grow, thus these trees need to be taken down within 15 years or earlier. These aspects result in trees that are not adequately planned and planted, which means that trees die young and cause further difficulty to find a place for trees.

This lack of understanidng and integration of trees and the right experts working closely to the implementation process indicates path dependency and lack of mainstreaming that were also mentioned by several authors in the literature review (Kabisch et al., 2022; Sarabi et al., 2019; van der Jagt et al.,2023; Adams et al., 2023). Lack of information was mentioned in the literature to be a barrier (Muñoz Sanz et al., 2022). However in the case of Leeuwarden it seems that the issue is not the lack of information but rather the distribution of the information. The interviewees indicate that

the current path dependency doesn't include enough expertise on trees in all projects and the general planning. It was suggested that a more collaborative approach regarding planning as well as budgeting with different stakeholders is needed. This supports the sources reviewed in the literature review that found that one of the main barriers for trees to be the lack of coordination and collaborative decision making across municipal departments (*Back, & Collins, 202*2; Muñoz Sanz et al., 2022; Dorst et al., 2022).

Finance

The financial barrier is connected to the lack of space and inadequate planning which is partly caused by lack of collaboration and understanding between different actors. Two interviewees expressed that even though there is considerably more investment in the trees than before, it is still a barrier to a certain extent.

Two interviewees explained that the extra cost comes from the need to modify the existing infrastructure. They explained that due to the lack of space underground planting a tree, especially in the city centre, needs a lot of work and therefore is also highly costly. According to one interviewee the financial barrier is the case especially when a tree is planned to a place where there is not space for it or trees have not been taken into account in constructing other infrastructure. Furthermore, if the tree is planted in a place where it can not grow old and needs to be removed and replaced after a period of time, it causes more costs and less ecosystem services reported by one the interviewee.

At the moment, many actors and decision makers involved do not have a realistic understanding of the cost of planting the trees according to one interviewee. This makes executing the plans highly challenging as there is a mismatch between the desired outcome and the allocated money for the projects. One of the interviewees commented that even though there is quantity wise more money, the decision makers would need to understand the long term viability of the planted trees, to make investments that are realistic and feasible in the long term. One interviewee suggested if the conditions that trees need are realistically taken into account while planning any infrastructure, the financing would be more efficient and future proof.

The existing lack of money seems to be closely connected to the dense infrastructure and the lack of collaboration and making the right decisions. Therefore the financial barrier is not that much about the amount of the money but rather stems from other barriers that cause more expenses. This relates to the reviewed literature as the limited financing was also mentioned to be a barrier but not ranked as high as other barriers (Dorst et al., 2022; Muñoz Sanz et al., 2022; back and Collins 2022).

Environmental conditions

Other barriers mentioned in the interviews were related to the harsh environmental conditions, for example the increase in diseases and the pressure from the traffic. One Interviewee explained that the urban trees are vulnerable to diseases such as Dutch elm disease. The prevalence of diseases was seen to be increasing due to climate change. Furthermore the interviewee explained that cars, buses and pedestrians pose a high pressure for the roots of the trees. In terms of traffic, another interviewee also pointed out that the way city centres are planned, should promote less car driving. For example no public parking or bigger grocery stores should be removed to have less traffic. One of the interviewees expressed the need for reducing car traffic in the city centre and connected to the liveability and ambiance of the city centre.

These results are in line with the literature that also ackknowledged the challenging biodiversity in urban areas (Kabish et al., 2022). Furthermore this can be also connected to the competition with the other infrastructure (Dorst et al., 2022). These results also imply the interconnectedness of different sectors in urban planning as the grocery stores affect traffic and thus also the trees. In addition to the experienced barriers, enablers and opportunities for the uptake and implementation of trees to respond to the UHI were identified. These will be presented and discussed in the next section.

Enablers and Opportunities for the uptake and implementation of trees

Political will and citizen engagement

The main enabler in all of the interviews was the increasing interest and acknowledgement of the multiple benefits and ecosystem services trees can provide to the city and its inhabitants. Therefore there is an increase in motivation among different actors across all levels. This has been directly seen in more funding, experiments and collaboration for greenery in general. One of the interviewees experienced that politics has a significant effect on tree planting, and lately there has been more interest and positive change as trees are taken seriously. Two interviews reported the enabler to be increasing acknowledgement of the multiple benefits and ecosystem services trees can provide to the city and its inhabitants. Therefore there is increasing motivation among different actors across all levels. Two of the interviews expressed that even though funding is always a challenge, there has been a significant amount of funding for trees in Leeuwarden due to the overall increase in interest. One interviewee expressed that especially during the past five years there has been significant increase in financial support.

Contrary to the literature review (Sarabi et al., 2019), in Leeuwarden there seems to be no or very little uncertainty about the benefits of NBS. Rather, the interviews indicate that the understanding of the wide variety of benefits and ecosystem services worked as a driving force among citizens and politicians.

Knowledge, Collaboration and experiments

The increase in people who are motivated to work to get more money and have a realistic approach to what trees need in order to grow where it is possible to plant a tree and where not was perceived to be the biggest enabler. Furthermore it was mentioned in one of the interviews that the municipality is collaborating with research institutions to continuously understand better the specific benefits ecosystem services trees can provide in Leeuwarden. The findings from one interviewee emphasised the significance of an ecosystem approach in tree planning. Therefore the plans for trees include collaboration with E. G. climate adaptation and biodiversity specialist. Furthermore, due to

the presence of diseases, one interviewee stresses that it is crucial to increase the diversity of tree species being planted. One of the interviewees mentioned an upcoming greening strategy that the municipality is currently preparing. In this strategy different environmental and social factors are mapped and compared in order to create feasible plans where to plant trees. This involves for example the identification of the warmest areas, amount of space and groundwater levels. They are also working with the citizens to understand their needs and wishes for tree placements. One of the interviewees stressed that there is potential for more collaboration in the planning and enforcement phase. It was stressed that greenery should be an integral part of the plan making phase, as it is currently not the case as mentioned in the barrier. The participant stressed that if experts from different fields (greenery and other infrastructure) get together in the planning phase to aggregate different components together in a feasible way. Thus much of the previously mentioned collateral damage could be avoided.

These results are in line with Sarabi et al., (2019) and Martin et al., (2021) and Adams et al., (2023). They also argue that collaboration and polycentric governance was one of the key enablers. Furthermore the importance of co-designing, integrating and distributing knowledge across the different sectors was highlighted (Sarabi et al., 2019; Martin et al., 2022; Adams et al., 2023). Furthermore these results imply that even though trees take space to plant, the benefits of the trees are largely acknowledged as mentioned also by Cortinovis et al., (2022) that trees are the most space-effective NBS

All interviews expressed that the Bosk ‘walking’ forest as an experiment was perceived to enhance citizen support and engagement. Bosk showed the people in real life how it actually changes the livability of the city centre when there are trees, according to all of the interviews. Two of the interviews indicated that after the Bosk different stakeholders were inspired to come together to create and finance new, permanent greening strategies. During the Bosk experiment the city was able to monitor how much cooler the areas were when the trees were present. An example raised in two interviews was the new tree project at the Waagplein square that was a direct result of the Bosk. This was an area where the temperature was monitored and experienced to be one of the highest. One interviewee explained that after the Bosk trees were in this square, people realised they needed trees

there in the centre of the city. Two of the interviews explained that as the trees are multifunctional, they create a good potential for collaboration. The new trees planted in Waagplein not only help to address the heat stress but also with excess water by preventing flooding, improving air quality and the overall atmosphere for the city dwellers. This way there were different stakeholders got interested to invest in this greenery project, which made the funding easier, reported one of the interviewees.

These results are in Lin Sarabi et al.,(2019) who also argued experiments to be an effective strategy to implement NBS. In accordance with the present results Sarabi et al.,(2019) also explained the experiments to demonstrate visible activity that encourages conversation with potential to change perceptions. Furthermore the Bosk Experiment seemed to facilitate many enablers that were also acknowledged in the literature such as collaboration, distribution of knowledge, citizen engagement, knowledge change (Sarabi et al., 2019; Martin et al., 2022; Adams et al., 2023)

One interviewee mentioned that one enabler was also the municipality's efforts to encourage and collaborate with private landowners. The city offers subsidies to people if they choose to implement greenery. One of the examples was a successful initiative when the city gave trees for free to people to plant into their garden. One interviewee explained that collaborating with the private sector was important in those areas of the city where the municipality does not have much land, so trees can be planted to companies' yards.

EU policies

The role of the EU was perceived differently among the participants. One participant explained that the plans and actions were mainly coming from “bottom up”, so from the municipality and the citizens. Therefore the role of the EU was not experienced as significant, but definitely not hindering. In another interview it was pointed out that many of the municipality plans are also connected to the EU targets and for the practical level the EU's role is encouraging and good. One interviewee expressed a slight indication that it could be challenging for the decision makers in the municipality to comply and realise the EU plans. Another interviewee reflected that the role of the EU should be to have long term goals. Furthermore it was mentioned that the EU could have a more explicit role in terms of advocating and funding NBS and trees in municipalities, as the participant

experienced the EU not advocating greenery clearly. One interviewee argued that the EU should not decide extensively how municipalities should implement these on a local level, as the local actors know best what works in the specific location.

These results support the arguments in the literature, that the EU policy framework needs to be adaptable to local implementation and leave room for sovereignty, while ensuring the targets are realised (Calliari et al., 2022). Based on these interviews, the non binding form of EU policies does not seem to be a hindering factor in the case of Leeuwarden, as action is being taken regardless of EU. These results do not seem to indicate that there should be more binding targets in EU policies, but rather the EU should focus on advocating and funding more explicitly. However the binding targets might work better than voluntary. These results also indicate that they seem to have a bigger possibility for tree related plans to be long term focused and continue over election cycles if they are connected to EU plans. This connects to the barriers mentioned in the reviewed literature by (Muñoz Sanz et al., 2022) as well as Back, & Collins, (2022) who found that local politicians prioritise often the short term benefits such as the aesthetical side of the trees.

The interviews reflect on the lack of quantifiable and measurable targets in general. According to the literature, there is a lack of measurable aspects within the EU policies (Calliari et al., 2022). The results of the interviews and other reviewed literature indicate that any addition to quantifiable and measurable targets (local or international level) should focus on the quality and the long term feasibility rather than number of trees. This means focusing on the quality and variety of measurable ecosystem services and size of the tree canopy cover. As mentioned in the literature review, study showed that 30% tree cover coverage is estimated to significantly reduce heat related mortality (lungman et al.,2030). Similarly the reviewed EU Biodiversity Strategy for 2030, a legally binding target for urban trees, is indeed connected to the tree canopy cover, specifically being 10% by 2050 (European Commission, 2022b). In line with the research and the EU policy, the local plan of Leeuwarden also includes a focus on the increase of tree canopy cover and not only the number of trees. The local plan in Leeuwarden is more ambitious (10% by 2030) than the EU law (10% by 2050). This is in line with the view from one interview, which stressed that the role of the EU is to think of long term plans.

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As trees are actively used to adapt to environmental conditions like excessive heating while increasing biodiversity in Leeuwarden, they can be classified as an NBS and GI (Sowińska-Świerkosz & García, 2022). It seems that Leeuwarden is in a transition towards uptaking and implementing more trees as there is increasing political and citizen support. While there are a number of opportunities, some barriers remain hindering the uptake and implementation of trees effectively on a practical level . The main barriers identified were the lack of space underground, limited collaboration and integration, finance and environmental conditions. Most of the barriers and enablers brought in the interviews are highly interconnected and dependent on each other. For example the lack of space and high financial cost were both partly due to plans that were not realistic or not executed well. The enablers mentioned in the interviews directly addressed this issue; Trees should be a more integrated part of any infrastructure plan and enforcement. When considering trees as an NBS for adapting to urban heat, the way trees are practically managed is crucial for it to deliver those ecosystem services that help mitigate the heat (Winbourne et al., 2020) Compared to other NBS solutions such as green roofs, trees provide a wider variety of ecosystem services and benefits to the city (Cortinovis et al., 2022). However in order to deliver those services, the trees also need more space and specific conditions. Therefore trees need to be implemented in the right way and they need the right conditions to grow optimally to deliver enough shading and other services.

The result of this study indicates that in order to implement trees as a NBS successfully, there needs to be adequate co-designing across different sectors as well as more collaboration with decision makers. Furthermore these findings reflect those of Dorst et al., (2022) who explain that collaboration, awareness, implementation, enforcement are barriers for mainstreaming NBS in general. This can be connected to (Martin et al., 2021; Adams et al., 2023) who suggests that the co-creation and polycentric governance should be facilitated by institutional planning systems and governance structures (Martin et al., 2021; Adams et al., 2023).

5. Limitations:

There are a number of limitations to this study. The responses of the key informant interviews are not representative as the scope of the participant was small and did not represent a variety of different stakeholders. Thus this study provides only insights on the knowledge and experienced barriers and enablers. Further research with a larger number of interviews is needed to have a better understanding of the case area. The experienced role of the EU in the decision making and policies in Leeuwarden remained rather vague in this research. Regarding the case study area, this study does not include local policy document analysis, due to language barrier. Future research on comparative policy analysis between EU and local policy documents, would give a more deeper understanding of the relation between municipal policies and EU policies.

6. Conclusion

The aim of this study was to provide insight into the barriers and enablers experienced with implementing trees to address urban heat in Leeuwarden. In conclusion, the main barriers identified in the interviews were the lack of space, insufficient integration of trees into the general planning, lack of collaboration, financial constraints, and environmental challenges. However there are a number of enablers and opportunities to overcome these challenges such as a positive political mindset among citizens and decision-makers, increasing motivation and knowledge and collaboration and experiments. These are becoming more prominent, presenting great opportunities to overcome the experienced barriers. Even though the EU policies regarding NBS and urban trees are still mainly voluntary, they were experienced to play a role in achieving long term goals that last over electoral cycles. Otherwise the role of the EU was seen on one hand as an inspiring and encouraging factor and on the other hand not very significant or necessary.

The results highlight the need for connectivity of the practical side to decision making and the need for more cross-sectoral collaboration. In order to use trees as an adaptation strategy for urban heat, the trees need to be seen as an integral part of the infrastructure. This way trees can provide the ecosystem services that mitigate heat. Additionally this allows multiple stakeholders to benefit from the tree investments and thus creates opportunities for co-funding. Therefore there seems to be still a

need for more collaborative strategies involving a range of stakeholders, especially in terms of coordination, funding, and expertise. In conclusion, if trees and NBS in general are understood as an integral part of the infrastructure, and are mainstreamed to the decision making and urban planning, there are more possibilities to make feasible decisions that also work in the long term.

7. Sources

Adams, C., Frantzeskaki, N., & Moglia, M. (2023). Mainstreaming nature-based solutions in cities: A systematic literature review and a proposal for facilitating urban transitions. *Land Use Policy*, *130*, 106661. https://doi.org/10.1016/j.landusepol.2023.106661

Alves, A., Vojinovic, Z., Kapelan, Z., Sanchez, A., & Gersonius, B. (2020). Exploring trade-offs among the multiple benefits of green-blue-grey infrastructure for urban flood mitigation. *Science of The Total Environment*, *703*, 134980. https://doi.org/10.1016/j.scitotenv.2019.134980

Ascione, F., De Masi, R. F., Mastellone, M., Santamouris, M., Tariello, F., & Vanoli, G. P. (2022). The Trend of Heat-Related Mortality in European Cities. In N. Aghamohammadi & M. Santamouris (Eds.), *Urban Overheating: Heat Mitigation and the Impact on Health* (pp. 293–320). Springer Nature. https://doi.org/10.1007/978-981-19-4707-0_15

Attride-Stirling, J. (2001). Thematic networks: An analytic tool for qualitative research. *Qualitative Research*, *1*(3), 385–405. https://doi.org/10.1177/146879410100100307

Back, P., & Collins, A. M. (2022). Negotiating the green obstacle course: Ranking priorities and problems for municipal green infrastructure implementation. *Urban Forestry & Urban Greening*, *67*, 127436. https://doi.org/10.1016/j.ufug.2021.127436

Bona, S., Silva-Afonso, A., Gomes, R., Matos, R., & Rodrigues, F. (2023). Nature-Based Solutions in Urban Areas: A European Analysis. *Applied Sciences*, *13*(1), Article 1. https://doi.org/10.3390/app13010168

Bosk – Groen Leeft in Leeuwarden. (n.d.). https://www.groenleeftinleeuwarden.nl/wat-doet-de-gemeente/bosk/

Calliari, E., Castellari, S., Davis, M., Linnerooth-Bayer, J., Martin, J., Mysiak, J., Pastor, T., Ramieri, E., Scolobig, A., Sterk, M., Veerkamp, C., Wendling, L., & Zandersen, M. (2022). Building climate resilience through nature-based solutions in Europe: A review of enabling knowledge, finance and governance frameworks. *Climate Risk Management*, *37*, 100450. https://doi.org/10.1016/j.crm.2022.100450

Castellari, S., Zandersen, M., Davis, M. European Environment Agency, (2021). *Nature-based solutions in Europe policy, knowledge and practice for climate change adaptation and disaster risk reduction*, Publications Office of the European Union.. https://data.europa.eu/doi/10.2800/919315

Calfapietra, C., & Cherubini, L. (2019). Green Infrastructure: Nature-Based Solutions for sustainable and resilient cities. *Urban Forestry & Urban Greening*, *37*, 1-2. https://doi.org/10.1016/j.ufug.2018.09.012

Cities Northern Netherlands. (n.d.). Leeuwarden - most favourable for Circular Economy. https://www.citiesnorthernnetherlands.eu/cities/leeuwarden/

Cohen-Shacham, E., Andrade, A., Dalton, J., Dudley, N., Jones, M., Kumar, C., Maginnis, S., Maynard, S., Nelson, C. R., Renaud, F. G., Welling, R., & Walters, G. (2019). Core principles for successfully implementing and upscaling Nature-based Solutions. *Environmental Science & Policy*, *98*, 20–29. https://doi.org/10.1016/j.envsci.2019.04.014

Cortinovis, C., Olsson, P., Boke-Olén, N., & Hedlund, K. (2022). Scaling up nature-based solutions for climate-change adaptation: Potential and benefits in three European cities. *Urban Forestry & Urban Greening*, *67*, 127450. https://doi.org/10.1016/j.ufug.2021.127450

Davies, C., Chen, W. Y., Sanesi, G., & Lafortezza, R. (2021). The European Union roadmap for implementing nature-based solutions: A review. *Environmental Science & Policy*, *121*, 49–67. https://doi.org/10.1016/j.envsci.2021.03.018

Dorst, H., van der Jagt, A., Toxopeus, H., Tozer, L., Raven, R., & Runhaar, H. (2022). What's behind the barriers? Uncovering structural conditions working against urban nature-based solutions. Landscape and Urban Planning, 220, 104335.https://doi.org/10.1016/j.landurbplan.2021.104335

de Oliveira, J. A. P., Bellezoni, R. A., Shih, W. Y., & Bayulken, B. (2022). Innovations in Urban Green and Blue Infrastructure: Tackling local and global challenges in cities. *Journal of Cleaner Production*, *362*, 132355. https://doi.org/10.1016/j.jclepro.2022.132355

Escobedo, F. J., Giannico, V., Jim, C. Y., Sanesi, G., & Lafortezza, R. (2019). Urban forests, ecosystem services, green infrastructure and nature-based solutions: Nexus or evolving metaphors? *Urban Forestry & Urban Greening*, *37*, 3–12. https://doi.org/10.1016/j.ufug.2018.02.011

Etikan, I., Musa, S. A., & Alkassim, R. S. (2016). Comparison of convenience sampling and purposive sampling. *American journal of theoretical and applied statistics*, *5*(1), 1-4.https://d1wqtxts1xzle7.cloudfront.net/55796997/Comparison_Convenience_and_Purposive_Sampling-2016_4p-libre.pdf?1518575584=&response-content-disposition=inline%3B+filename%3DComparison_of_Convenience_Sampling_and_P.pdf&Expires=1680274181&Signature=QfBMt26Lkge7R~zcS8fLTsSSpvtUdQcrXs0dQHNpEX28tPdDupcG80jBj9G65cnvV-q65Yxk7fJk7MXjoscvBYaI-625RXGVbZjJElL-GjrD7d3t9fCok78K13t-P0vdvd-zWpEoqDh3gk~gFhonclJIHJPCg9fS7of3bh5quPmbPy0Gt8m2Z~K2Ns00FbMxuDylG0Z77nMETfEBdmWf3yeazhjVmspN5zPCbKrwGztOiqE2ZDqYkIBfLWNzUq9HMwEPDXfZi0iI~bwW3HGG

hNV3qz8ta13TPUS3O7EyBcbvOvcQWFZK8XYorGg8XV0a5I-iwu2vf8Tn7B7GpDpJRg__&Key-Pair-Id=APKAJLOHF5GGSLRBV4ZA

European Commission. (2018a). *URBAN AGENDA FOR THE EU, Climate Adaptation Partnership. European Commission* https://futurium.ec.europa.eu/sites/default/files/2021-02/Climate%20Adaptation.pdf

European Commission. (2018b). *URBAN AGENDA FOR THE EU, Sustainable Use of Land and Nature-Based Solutions Partnership. European Commission* https://futurium.ec.europa.eu/sites/default/files/2021-02/Sustainable%20land%20use%20and%20nature%20based%20solutions.pdf

European Commission. (2020). EU Biodiversity Strategy for 2030, Bringing nature back into our lives. In *EUR-Lex*(No. 52020DC0380). Retrieved May 14, 2023, from https://eur-lex.europa.eu/resource.html?uri=cellar:a3c806a6-9ab3-11ea-9d2d-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Commission. (2021). New EU Forest Strategy for 2030. In *EUR-Lex* (No. 52021DC0572). Retrieved May 14, 2023, from https://eur-lex.europa.eu/resource.html?uri=cellar:0d918e07-e610-11eb-a1a5-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Commission. (2022a, June 22). *Green Deal: pioneering proposals to restore Europe's nature by 2050 and halve pesticide use by 2030* [Press release]. *https://ec.europa.eu/commission/presscorner/detail/en/ip_22_3746*

European Commission. (2022b). Proposal for a REGULATION OF THE EUROPEAN PARLIAMENT AND OF THE COUNCIL on nature restoration. In EUR-Lex (No. 52022PC0304). https://eur-lex.europa.eu/resource.html?uri=cellar:f5586441-f5e1-11ec-b976-01aa75ed71a1.0001.02/DOC_1&format=PDF

European Commission. (2023a, January 27). *Nature-based solutions*. Research and Innovation. https://research-and-innovation.ec.europa.eu/research-area/environment/nature-based-solutions_en

European Commission. (2023b, May 8). *Biodiversity strategy for 2030*. Environment. https://environment.ec.europa.eu/strategy/biodiversity-strategy-2030_en

European Commission, n.d. *The Urban Agenda for the EU* https://ec.europa.eu/regional_policy/policy/themes/urban-development/agenda_en#:~:text=The%20Urban%20Agenda%20for%20the%20EU%20is%20an%20integrated%20and,of%20life%20in%20urban%20areas.

European Environment Agency. (n.d.). *Urban tree cover*. https://www.eea.europa.eu/data-and-maps/dashboards/urban-tree-cover

Gemeente Leeuwarden. (2023, April 28). *Bosk - Gemeente Leeuwarden*. https://www.leeuwarden.nl/evenementen/bosk/

Hennink, M., Hutter, I., & Bailey, A. 2020. Qualitative Research Methods. London: Sage. second edition

Herzog, C., Freitas, T., Wiedman, G. European Commission, Directorate-General for Research and Innovation (2022). *Nature-based solutions and the challenges of water : accelerating the transition to more sustainable cities*, (C.Herzog, editor, T.Freitas, editor, G.Wiedman, editor) Publications Office of the European Union. https://data.europa.eu/doi/10.2777/95912

Iungman, T., Cirach, M., Marando, F., Barboza, E. P., Khomenko, S., Masselot, P., Quijal-Zamorano, M., Mueller, N., Gasparrini, A., Urquiza, J., Heris, M., Thondoo, M., & Nieuwenhuijsen, M. (2023). Cooling cities through urban green infrastructure: A health impact assessment of European cities. *The Lancet*, *401*(10376), 577–589. https://doi.org/10.1016/S0140-6736(22)02585-5

Kabisch, N. (2015). Ecosystem service implementation and governance challenges in urban green space planning—The case of Berlin, Germany. *Land Use Policy*, *42*, 557–567. https://doi.org/10.1016/j.landusepol.2014.09.005

Kabisch, N., Frantzeskaki, N., & Hansen, R. (2022). Principles for urban nature-based solutions. *Ambio*, *51*(6), 1388-1401. https://link.springer.com/article/10.1007/s13280-021-01685-w

Kennedy, W. (2022, December 28). *Leeuwarden scoort slecht op hittestress, gemeente wil stad veel groener maken*. Omrop Fryslân. https://www.omropfryslan.nl/nl/nieuws/1184042/leeuwarden-scoort-slecht-op-hittestress-gemeente-wil-stad-veel-groener-maken

Khandkar, S. H. (2009). Open coding. *University of Calgary*, *23*, 2009.http://pages.cpsc.ucalgary.ca/~saul/wiki/uploads/CPSC681/opencoding.pdf

Klimaatadaptatie. (n.d.). *Leeuwarden maakt gebiedsgerichte uitvoeringsagenda* https://klimaatadaptatienederland.nl/@249676/leeuwarden-uitvoeringsagenda/

Leeuwarden in Cijfers, bevolking, inwoners. (n.d). Accessed 4th of July 2023 https://leeuwarden.incijfers.nl/Jive?workspace_guid=33909e7b-1b2f-44b1-8e10-e62aaba7bdb1

Martin, J., Scolobig, A., Linnerooth-Bayer, J., Liu, W., & Balsiger, J. (2021). Catalyzing Innovation: Governance Enablers of Nature-Based Solutions. *Sustainability*, *13*(4), 1971. https://doi.org/10.3390/su13041971

Marando, F., Heris, M. P., Zulian, G., Udías, A., Mentaschi, L., Chrysoulakis, N., Parastatidis, D., & Maes, J. (2022). Urban heat island mitigation by green infrastructure in European Functional Urban Areas. *Sustainable Cities and Society*, *77*, 103564. https://doi.org/10.1016/j.scs.2021.103564

Marando, F., Salvatori, E., Sebastiani, A., Fusaro, L., & Manes, F. (2019). Regulating Ecosystem Services and Green Infrastructure: Assessment of Urban Heat Island effect mitigation in the municipality of Rome, Italy. *Ecological Modelling*, *392*, 92–102. https://doi.org/10.1016/j.ecolmodel.2018.11.011

Muñoz Sanz, V., Romero Muñoz, S., Sánchez Chaparro, T., Bello Gómez, L., & Herdt, T. (2022). Making green work: Implementation strategies in a new generation of urban forests. *Urban Planning*, *7*(2), 202–213. https://doi.org/10.17645/up.v7i2.5039

McDonald, R. I., Aronson, M. F. J., Beatley, T., Beller, E., Bazo, M., Grossinger, R., Jessup, K., Mansur, A. V., Puppim de Oliveira, J. A., Panlasigui, S., Burg, J., Pevzner, N., Shanahan, D., Stoneburner, L., Rudd, A., & Spotswood, E. (2023). Denser and greener cities: Green interventions to achieve both urban density and nature. *People and Nature*, *5*(1), 84–102. https://doi.org/10.1002/pan3.10423

Nordh, H., & Olafsson, A. S. (2021). Plans for urban green infrastructure in Scandinavia. *Journal of Environmental Planning and Management*, *64*(5), 883–904. https://doi.org/10.1080/09640568.2020.1787960

Raymond, C. M., Frantzeskaki, N., Kabisch, N., Berry, P., Breil, M., Nita, M. R., Geneletti, D., & Calfapietra, C. (2017). A framework for assessing and implementing the co-benefits of nature-based solutions in urban areas. *Environmental Science & Policy*, *77*, 15–24. https://doi.org/10.1016/j.envsci.2017.07.008

Research Rabbit [Internet]. Available from: https://researchrabbitapp.com/ home. Accessed 20.5.2023.

Salmanian, M., & Bayat, A. (2023). Urban heat island: A primary guide for urban designers. *Future Energy*, *2*(4), Article 4.

Sarabi, S., Han, Q. Q., Romme, A. G. L., Romme, A. G. L., A. Georges L. Romme, de Vries, B., & Wendling, L. (2019). Key Enablers of and Barriers to the Uptake and Implementation of Nature-Based Solutions in Urban Settings: A Review. *Resources*, *8*(3), 121. https://doi.org/10.3390/resources8030121

Winbourne, J. B., Jones, T. S., Garvey, S. M., Harrison, J. L., Wang, L., Li, D., ... & Hutyra, L. R. (2020). Tree transpiration and urban temperatures: current understanding, implications, and future research directions. *BioScience*, *70*(7), 576-588.https://academic.oup.com/bioscience/article/70/7/576/5857071

Schwaab, J., Meier, R., Mussetti, G., Seneviratne, S., Bürgi, C., & Davin, E. L. (2021). The role of urban trees in reducing land surface temperatures in European cities. *Nature Communications*, *12*(1), Article 1. https://doi.org/10.1038/s41467-021-26768-w

Sowińska-Świerkosz, B., & García, J. (2022). What are Nature-based solutions (NBS)? Setting core ideas for concept clarification. *Nature-Based Solutions*, *2*, 100009. https://doi.org/10.1016/j.nbsj.2022.100009

Sturiale, L., & Scuderi, A. (2019). The Role of Green Infrastructures in Urban Planning for Climate Change Adaptation. *Climate*, *7*(10), Article 10. https://doi.org/10.3390/cli7100119

Thanvisitthpon, N. (2023). Statistically Validated Urban Heat Island Risk Indicators for UHI Susceptibility Assessment. *International Journal of Environmental Research and Public Health*, *20*(2), Article 2. https://doi.org/10.3390/ijerph20021172

UNECE (The United Nations Economic Commission for Europe) (2021). *Policy brief: Sustainable Urban and Peri-urban Forestry - An Integrative and Inclusive Nature-Based Solution for Green Recovery and Sustainable, Healthy and Resilient Cities (EFR) | UNECE*. The United Nations Economic Commission for Europe. https://unece.org/forestry-timber/documents/2023/02/informal-documents/policy-brief-sustainable-urban-and-peri-urban

UN DESA (United Nations Department of Economic and Social Affairs). (2018, May 16). *2018 Revision of World Urbanization Prospects | United Nations*. United Nations. https://www.un.org/en/desa/2018-revision-world-urbanization-prospects#:~:text=Today%2C%2055%25%20of%20the%20world%27s,increase%20to%2068%25%20by%202050.

van der Jagt, A., Tozer, L., Toxopeus, H., & Runhaar, H. (2023). Policy mixes for mainstreaming urban nature-based solutions: An analysis of six European countries and the European Union. *Environmental Science & Policy*, *139*, 51–61. https://doi.org/10.1016/j.envsci.2022.10.011

Vaňo, S., Olafsson, A. S., & Mederly, P. (2021). Advancing urban green infrastructure through participatory integrated planning: A case from Slovakia. *Urban Forestry & Urban Greening*, *58*, 126957. https://doi.org/10.1016/j.ufug.2020.126957

Varbova, V. (2022). *Ex-ante Assessment of the Thematic Area "Greening Cities" under the Urban Agenda for the EU*. Retrieved May 14, 2023, from https://futurium.ec.europa.eu/system/files/2022-06/EAA%20Report%20Greening%20Cities.pdf

Wang, X. H., Wu, Y., Gong, J., Li, B., & Zhao, J. J. (2019). Urban planning design and sustainable development of forest based on heat island effect. *Appl. Ecol. Environ. Res*, *17*, 9121-9129. https://doi.org/10.15666/aeer/1704_91219129

Ward, K., Lauf, S., Kleinschmit, B., & Endlicher, W. (2016). Heat waves and urban heat islands in Europe: A review of relevant drivers. *Science of The Total Environment*, *569–570*, 527–539. https://doi.org/10.1016/j.scitotenv.2016.06.119

Zingraff-Hamed, A., Hüesker, F., Albert, C., Brillinger, M., Huang, J., Lupp, G., Scheuer, S., Schlätel, M., & Schröter, B. (2021). Governance models for nature-based solutions: Seventeen cases from Germany. *Ambio*, *50*(8), 1610–1627. https://doi.org/10.1007/s13280-020-01412-x

Appendix A

Ethical Considerations

Participation in this research was completely voluntary and anonymous. Participants had the right to refuse or withdraw their participation and consent to use the answers at any point of the research without any consequences or providing reasons. Any refusal or withdrawal decision is only accessible to the researcher. In addition when using a snowball sampling, the person connecting the researcher with the possible participant was not informed of the participants choice to withdraw or accept the invitation. Before interviews participants were provided an information sheet and consent form to sign. In addition verbal consent was asked for the participation and audio-recordings for transcription. Throughout the research process, it was ensured that all the data was kept private. The data was analysed confidentially, implying that the data is stored securely. All personal identifiers were removed from the collected data and the results were analysed anonymously without including a description of affiliation to any specific department. During the writing process the anonymised results were shared with the supervisor and other students for peer review purposes. The data will be stored according to the General Data Protection Regulation (GDPR) rules of the University of Groningen. All transcripts and recordings are destroyed after the research is finished, in July 2023.

Appendix B

INFORMATION SHEET

Title of the study: Urban trees as an adaptation strategy to urban heat in Leeuwarden.

Dear Participant,

Thank you for your interest in participating in this research. This letter explains what the research entails and how the research will be conducted. Please take time to read the following information carefully. If any information is not clear kindly ask questions using the contact details of the researcher provided at the end of this letter.

WHAT THIS STUDY IS ABOUT?

This research aims to explore: How trees and forests can be implemented in urban areas as an adaptation strategy to urban heating in Leeuwarden. The aim of the interviews is to understand current practices and approaches used as well as the experienced enabling factors and barriers for the implementation of trees in urban areas in Leeuwarden.

WHAT DOES PARTICIPATION INVOLVE?

The interview is constructed by guiding questions posed by the interviewer. However, the interviewee is encouraged to elaborate on the topic to the extent wished for. You are asked to answer the questions based on your own experience and perceptions. The interview is expected to last about 30 minutes.

DO YOU HAVE TO PARTICIPATE?

Participation in this research is voluntary. You, as a participant, have the right to refuse or withdraw your participation and consent to use the answers at any point of the research without any consequences or providing reasons. Any refusal or withdrawal decision is only accessible to the researcher and the supervisor of the research. This information will not be shared with any other person at the University of Groningen or a third party. At any point of the interview, you have the right to refuse answering questions without consequences or an explanation of the reason.

ARE THERE ANY RISKS IN PARTICIPATING?

There are no risks for participants that participate in the research. All data will be kept private, meaning that personal identifiers are removed from the collected data. The data will be analyzed confidentially, implying that the data is stored securely and is accessible only to the researcher.

ARE THERE ANY BENEFITS IN PARTICIPATING?

There are no direct personal benefits from this research.

HOW WILL INFORMATION YOU PROVIDE BE RECORDED, STORED AND PROTECTED?

If the participants provide their consent, the interviews will be audio recorded for transcription. In case the participants do not consent to the interviews being recorded, notes will be taken manually. The researcher will ensure that all the

data will be stored and kept private. Only the researcher will have access to the interview recordings. All personal identifiers will be removed from the collected data. This means that the results of the collected data will be analysed anonymously. During the writing process the anonymised result will be shared with the supervisor and other students for peer review purposes. Any transcripts shared will contain only anonymised data including general descriptions of participants, without including a description of affiliation to any specific organisation or department. The data will also be stored according to the General Data Protection Regulation (GDPR) rules of the University of Groningen. All data will be destroyed after the research is finished in July 2023.

WHAT WILL HAPPEN TO THE RESULTS OF THE STUDY?

The results of the data collection will be part of a written bachelor thesis. The results of this study will be analysed in a research report. This report will be graded by the University of Groningen. The results will be shared with the university of Groningen.

Appendix C

INFORMED CONSENT FORM

Title study: Urban trees as an adaptation strategy to urban heat in Leeuwarden
Name of the participant:

Assessment

• I have read the information sheet and was able to ask any additional questions to the researcher.
• I understand I may ask questions about the study at any time.
• I understand I have the right to withdraw from the study at any time without giving a reason.
• I understand that at any time, I can refuse to answer any question without any consequences.
• I understand that I will not benefit directly from participating in this research.

Confidentiality and Data Use

• I understand that none of my individual information will be disclosed to anyone outside the study team, and my name will not be published.
• I understand that the information provided will be used only for this research and publications directly related to this research project.
• I understand that data (consent forms, recordings, interview transcripts) will be stored in correspondence with the university GDPR legislation.

WHOM SHOULD YOU CONTACT FOR FURTHER INFORMATION?

Ilona Kauppila

Having read and understood all the above, I agree to participate in the research study:
yes / no

Date **Signature**

To be filled in by the researcher

• I declare that I have thoroughly informed the research participant about the research study and answered any remaining questions to the best of my knowledge.
• I agree that this person participates in the research study.

Date **Signature**