Master's thesis

NTNU
Norwegian University of Science and Technology
Faculty of Social and Educational Sciences
Department of Geography

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Assessing the social impact of a Nature-based Solution in Trondheim Municipality

A neighbourhood-scale socio-spatial analysis

Master's thesis in Globalisation and Sustainable Development
Supervisor: Martina Calovi
Co-supervisor: Hilde Nymoen Rørtveit
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Abstract

Nature-based Solutions are an alternative approach to climate adaptation that deliver many co-benefits. Trondheim municipality in 2006 in a transformative project created a park which holds part of a renatured stream and a detention pond. The project has been viewed as very successful; however, no social impact assessment has been carried out since its creation and the municipality is missing tools for communicating the benefits of alternative solutions to its citizens. It is argued that Nature-based Solutions should be monitored and assessed after their creation to see whether they are performing well, solving the issue which they were designed for and to create nuanced knowledge. This study utilized three indicators to assess whether the park containing NbS had a positive, neutral or negative impact on the local society. Citizens' perception and impact on life were assessed through an online survey. Health and wellbeing through remote sensing, focusing on Normalized Difference Vegetation Index change before and after the park's creation. Lastly, economic efficiency has been assessed through cost-benefit analysis. Costs have been obtained from the Trondheim municipality and Ecosystem services with iTree Canopy software and other sources. The results were positive, Residents of the neighbourhood had a very positive outlook on the park and its implications, the majority also believed that the park affects their quality of life in a positive manner. The Normalized Difference Vegetation Index value improved in the years after the park's creation compared to before. Assessing the economic efficiency showed many limitations, and its outcome was negative. In summary with additional background data on the neighbourhood life and changes in the city, Iladalen Park proved to have a positive impact on local society and posed positive implications for the residents.

Keywords: Nature-based solutions, Climate adaptation, Urban nature, Wellbeing, Ecosystem Services, NDVI, Assessment, Interdisciplinary

Sammendrag

Naturbaserte løsninger er en alternativ tilnærming til klimatilpasning som gir mange tilleggsgoder. Trondheim kommune etablerte i 2006 en park som en del av et bytransformasjonsprosjekt, hvor Ilabekken ble gjenåpnet og et fordrøyningsbasseng ble anlagt. Prosjektet har blitt løftet frem som svært vellykket, men det har ikke blitt gjennomført en analyse av sosiale virkning siden parken ble etablert og kommunen mangler verktøy for å kommunisere fordelene ved å ta i bruk naturbaserte løsninger til innbyggerne. Det argumenteres for at naturbaserte løsninger bør overvåkes og evalueres etter at de er etablert for å kunne vurdere hvor godt de fungerer, om de løser det problemene de ble utviklet for, og for å bidra til mer nyansert kunnskap. I denne studien ble det brukt tre indikatorer for å vurdere om parken med NbS hadde en positiv, nøytral eller negativ innvirkning på lokalsamfunnet. Innbyggernes perspektiv på parken og hvilken innvirkning den har på hverdagslivet ble undersøkt gjennom en nettbasert spørreundersøkelse. Helse og velvære ble vurdert ved hjelp av en analyse av fjernmåling, med fokus på endringer i Normalized Difference Vegetation Index før og etter parkens opprettelse. Til slutt har den økonomiske effekten blitt vurdert gjennom en kost-nytte-analyse. Kostnadene er innhentet fra Trondheim kommune og økosystemtjenester med iTree Canopy-programvaren og andre kilder.
Resultatene fra undersøkelsen var positive: Beboerne i nabolaget hadde et svært positivt syn på parken og dens tilleggsgoder. Flertallet mente også at parken påvirker livskvaliteten deres på en positiv måte. NDVI har klart forbedret seg i årene etter at parkene ble opprettet sammenlignet med før. Den økonomiske effektten viste derimot mange begrensninger, og resultatet var negativt.
Oppsummert, med ytterligere bakgrunnsdata om livet i nabolaget og endringer i byen, viste Iladalen Park seg å ha en positiv innvirkning på lokalsamfunnet med positive konsekvenser for innbyggerne.

Nøkkelord: Naturbaserte løsninger, Klimatilpasning, Bynatur, Trivsel, Økosystemtjenester, NDVI, Vurdering, Tverrfaglig

Preface

I want to dedicate this Master thesis to all Palestinians who never got to finish their education and follow their dreams due to the violence of the occupation and discrimination.
My heart and mind have been with them through these last months of my education.

I am deeply grateful to my advisors Martina and Hilde, for their invaluable guidance and support from day one. I struggled a lot in the beginning of this research, their encouragement and patience helped me move forward. They created an atmosphere where I could enjoy the work without the fear of deadlines.

I would also like to thank Ronja Lappe for her generous help and sharing her expertise in remote sensing, as well as Mahdi Bahrami and Maria Gonzalez for helpful discussions on Nature-based Solutions in Trondheim.
Lastly, I want to thank my partner and my classmates for these last two years in Trondheim. They made Norway feel like home.

Joanna Radkiewicz
Trondheim, May 14th 2024

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List of Abbreviations

SES	Social-Ecological Systems
NbS	Nature-based Solutions
IUCN	International Union for Conservation of Nature
NDVI	Normalized Difference Vegetation Index
GDP	Gross Domestic Product

1 Introduction

Over 55% of today's world population lives in cities, and it has been predicted that this number will reach 70% of the world's constantly growing population by the year 2050 (World Bank, 2023). Intensifying climate change can have a significant impact on urban areas and moreover on the lives of urban dwellers. Intensified heat island effect, extreme weather events such as floods and landslides, sea level rise and droughts affect urban dwellers around the world (Gasper et al., 2011). Drainage is very often reduced in urban areas which, in the event of intensifying rainfall can lead to increased flooding. With that, infrastructure, citizens wellbeing and livelihoods are at risk. The heat island effect intensifies with rising temperature, increasing health-relates issues affecting especially the vulnerable part of urban population, such as elders. Gasper et al. (2011) also underlines potential food and water insecurity, displacement and economic impacts such as damage to infrastructure or energy shortages interrupting services and businesses. Biodiversity loss is another great challenge, and it is in fact clearly interconnected with climate change and human society (Johnson et al., 2022). Deforestation and expansion of urban areas can lead to the loss of biodiversity and contribute to climate change through the interruption of ecosystems and release of greenhouse gases. For this reason, Johnson et al. (2022) argues that these issues should not be addressed or discussed separately. Nature-based Solutions (NbS) are one of the approaches to climate adaptation that attempt to address these interconnected issues together. NbS utilize benefits of different ecosystems and nature features to adapt human environments to climate change and protect biodiversity (Johnson et al., 2022). Thus, although used both in rural and urban context they promise many benefits to the urban dwellers in the light of intensifying weather events and biodiversity loss.

1.1 Nature-based Solutions

What are NbS and what defines them? They were first mentioned by the World Bank in 2008 (MacKinnon et al., 2008), and as a concept they were developed in the search for solutions which would benefit humans and nature at once. The main idea is to work with nature and

utilize its aspect to create solutions to societal challenges, such as climate change (Sowińska-Świerkosz & García, 2022). There is many commonly agreed with definitions of NbS provided by actors such as European Commission, World Bank or International Union for Conservation of Nature (IUCN). These tend to be general, and they do not help to identify NbS among other types of green infrastructure or green solutions (Sowińska-Świerkosz & García, 2022). An analysis of 20 definitions of NbS from 200 papers shows that they essentially refer to interventions inspired and powered by nature, which are to address challenges, provide multiple benefits such as biodiversity enhancement and which are supposed to be effective and economically efficient (Sowińska-Świerkosz & García, 2022).

Although being inspired by nature or utilizing ecosystem services is at the core of NbS it takes more than that. They have to be based on functioning ecosystems and they must be intentional, meaning that their goal has to be clearly defined and their design and implementation have to be deliberately planned for that goal. Randomly planted tree is not a NbS. Furthermore, NbS and their success are context-specific, there is not one solution to be implemented and successful everywhere (Sowińska-Świerkosz & García, 2022). Their shape, size and type of ecosystem used varies on the societal challenge which it is to address, depends on the geographical zone and its climate, local culture, actors involved, local biodiversity and local context. Successful examples of solutions can be recreated but with adaptation to the local context (Sowińska-Świerkosz & García, 2022).

To make the concept more explicit IUCN created a global standard for NbS which helps to further clarify which initiatives can be referred to as NbS. Their standard boils down to eight criteria: NbS effectively address societal challenges, design of NbS is informed by scale, NbS result in a net gain to biodiversity and ecosystem integrity, NbS are economically viable, NbS are based on inclusive, transparent and empowering governance processes, NbS equitably balance trade-offs between achievement of their primary goal(s) and the continued provision of multiple benefits, NbS are managed adaptively, based on evidence, NbS are sustainable and mainstreamed within an appropriate jurisdictional context (IUCN, 2020).
Few examples of NbS in urban context include urban forests, river and stream renaturation, green corridors, urban farming, and bioretention areas (World Bank, 2021).
NbS are now receiving a lot of attention in Europe and Scandinavia as in recent years considerate funding into research and innovation projects has been provided by European Commission and Nordic Council of Ministers (European Research Executive Agency, n.d.;

Nordic Co-operation, 2021).

Reopening of rivers and streams as a NbS became a popular practice and a political objective in Oslo, Norway. The municipality already reopened a number of waterways which have previously been locked in pipes underground and made rivers available for the citizens. Oslo municipality is now working on more streams and rivers to deal with climate change and adapt to heavier rainfall (Oslo Municipality, 2022). Great example of successful initiative of this character is reopening of Hovinbekken. Hovinbekken previously mostly closed is now in 70% open, runs through multiple parks in Oslo and is currently undergoing further works (Oslo Municipality, 2022, p. 14). Oslo's waterway objective aids in improving urban ecology as reopened streams re-invite birds, insects, badgers and other animals while improving fish environment. Oslo municipality therefore tackles societal challenges, improves biodiversity and creates a more attractive blue-green city through this approach (Oslo Municipality, n.d.).

1.2 Case study background

Initiatives, such as those described above, on a smaller scale, have already been undertaken by Trondheim Municipality in early 2000's. Trondheim reopened Ilabekken, a small watercourse starting up in the local forest- Bymarka. The last 700 meters of the stream, from a dam till the exit to the Fjord have been reopened to reduce flooding, increase biological diversity and strengthen a blue-green structure between the Bymarka forest and Trondheimsfjord fjord (NVE, 2022). The latter included the establishment of Iladalen Park, which is at the centre of this research.

Stream reopening and park creation were a part of a bigger project, transforming the local area by creating a relief road which now runs beneath the park (NVE, 2022). This entailed a huge transformation of the area and construction works period varied for different features of the project. Stream reopening and park construction have been built between 2006 and 2008 (NVE, 2022). However, the road construction has been ongoing on from 2004 until the end of 2009 (Byggeindustrien, 2007). Therefore, although the park was made available as an open recreational area in 2008, based on the aerial photos it only started becoming green from 2009 on (Statens Kartverk, n.d.). The whole project of creating the relief road, park and stream opening has been a cooperation between Trondheim Municipality and the Norwegian

Public Roads Administration.

Ilabekken, which catchment area is of 9,7 km^2 was reopened in a nature-like manner contributing to the biodiversity by producing space for trout, ducks, salamanders, frogs and bats in the reopened rocks. The stream, before reaching the fjord goes through the park and through the detention pond. Ilabekken is also a large capacity floodway (Asplan Viak AS, 2016; NVE, 2022).

In 2010 Trondheim received the State's Urban Environment Award for the re-opening of Ilabekken from the Ministry of Environment. Trondheim won for long-term, interdisciplinary thinking and good use of water's ecosystem services. The project exemplified good cooperation between the Municipality and National Road Administration and their separate agendas discussed above. Building a relief road while opening the stream and inviting citizens to enjoy its course and the park (See Figure 5), was said to have an impact on the city beyond the watercourse itself (Miljøverndepartementet, 2010). A recent report presented by the Norwegian Institute for Water Research states that today there is a good population of seatrout in lower parts of the stream (See Figure 4) (Nesheim et al., 2023, pp. 19-21). Iladalen Park is not a big open space, its area covers roughly 18.400 m^2, and in this research I refer to the park as a NbS, as it is a container for the two discussed below NbS: detention pond and

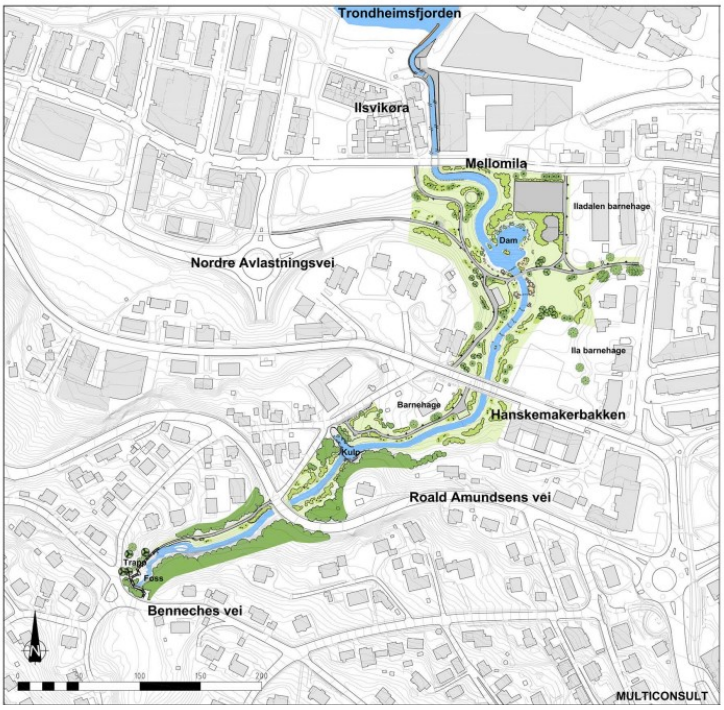


Figure 1. Overview of re-opened stream and Iladalen Park. From *Overvann som ressurs* (p. 126) by Asplan Viak AS, 2016. Original data by Multiconsult.

part of the re-opened stream (See Figure 1).

A stream and river renaturation as a NbS provides many benefits and desirable processes- one of the approaches to renaturation is reopening previously piped small urban streams (sometimes referred to as daylighting). This type of renaturation increases wildlife, improves wildlife habitat, regulates storm water and increases natural infiltration capacity. Reopening of streams could help avoid flooding, soil collapse and damages to build environment (World Bank, 2021, pp. 71-77). Renaturing of the stream banks regulates banks erosion, air pollution, water pollution, riverine flooding, pluvial flooding and heat. Other benefits include positive impact on human health through increased sense of wellbeing and through providing space for active exercise, and for social interaction (World Bank, 2021, pp. 71-77).

Detention ponds are a type of bioretention areas. Their goal is to capture and temporally store water from an intense rainfall and they are less biologically diverse than other types of bioretention NbS such as wetlands (World Bank, 2021, pp. 141-147). In periods of regular rainfall, they can be filled with water and play aesthetical role in public spaces as blue elements in urban landscape. In dry periods they can stand empty (World Bank, 2021).

Figure 3. Detention pond in Iladalen Park. Own work.

Figure 2. Re-opened Ilabekken stream in Iladalen Park. Own work.

That is the case for the detention pond in Iladalen Park. Additionally, as mentioned before, the course of the stream goes through the detention pond (See Figures 2 & 3), therefore with a heavy rainfall the detention pond captures water directly from the floodway. Outside of the pluvial flood regulation, bioretention areas fulfil heat regulation, water pollution regulation, soil pollution regulation and subsidence regulation functions. They provide opportunity for environmental education, social interaction and carbon storage and sequestration (World Bank, 2021, pp. 141-147).

Figure 4. Fishway in Iladalen Park. Own work.

Figure 5. Re-opened stream above Iladalen Park. Own work.

1.3 Problem Statement

Trondheim Municipality puts emphasis on implementing NbS in the Municipal Theme plan for climate adaptation (2022). Cooperation and participation are considered necessary for the successful adaptation. According to Trondheim Municipality, Trondheim's residents play vital role in the implementation of climate adaptation measures as stakeholders with localized knowledge. The plan even mentions Ilabekken and Iladalen Park as a success story since the park introduced more nature into the city while working towards climate adaptation (Trondheim Kommune, 2022). While the park and stream are mentioned in City's Online

Magazine dedicated to sustainability (Trondheim Kommune, 2016), the benefits derived from the park for the citizens have not been assessed or presented in further detail. NbS should be monitored, and their impact both for the nature and local community should be assessed to determine whether they are fulfilling their goals, weather there are problems or aspects that could be handled better. Collecting such information would also be beneficial in strengthening the dialogue with the citizens, it would aid in presenting proof for promised benefits (Raymond et al., 2017, p. 20; Raymond et al., 2017b). Such was the view of a Universitetskommunen (organisation bridging the municipality and the university in Trondheim) employee with who I met to discuss NbS in Trondheim (Universitetskommunen Trondheim, personal communication, November 10, 2023). During our conversation it became clear that the Municipality, although invested in the topic of NbS, doesn't have the data and resources to communicate with citizens about NbS in Trondheim.

NbS is still a relatively new concept, therefore assessing the performance and impacts and building knowledge on both successful and failure cases is crucial for further development of the field and for creating better NbS in the future (Raymond et al., 2017b). Wang and Kintrea (2019) argue that studies on sustainability and transformation in cities should be done at neighbourhood scale as well. It is a good scale to assess relationship between place, and quality of life- as life happens at the neighbourhood level (Wang & Kintrea, 2019). Lastly, citizens and stakeholders' acceptance of NbS projects is very important for their success, making social impact lense a relevant one (Giordano et al., 2020; Raymond et al., 2017b). Therefore, this thesis aims to fill these gaps and assess the social impact of a NbS on a local community in Trondheim, Norway. Through my research I intend to determine whether the social impact of Iladalen Park, as a NbS, is positive, neutral or negative and answer the following research question:
How is Iladalen Park as a Nature-based Solution performing in terms of social impact and what implications does it have for the local community?

Through this research I also hope to contribute to the general knowledge on NbS, their performance and impact on society.

2 Literature review

NbS, as explained before, are solutions created to manage natural systems and processes to benefit both the environment and the society inhabiting it. Therefore, at its core NbS are connected to the wellbeing of human communities (Sowińska-Świerkosz & García, 2022). Like with many other concepts, the precise definition of NbS varies, however Sowińska-Świerkosz and García (2022) attempt to define ideas lying at the core of the concept. They focus on environmental benefits, economic viability, balance of trade-offs and most importantly on addressing societal challenges. They suggest that NbS should address at least one of societal challenges which have been defined by the IUCN. These include climate change adaptation and mitigation, disaster risk reduction, ecosystem degradation and biodiversity loss, human health, socio-economic development, food security and water security (Sowińska-Świerkosz & García, 2022). Assessing NbS will therefore entail assessing the social impact.

Why is the social impact assessment relevant though? Kabisch et al. (2016) argue that assessment is necessary to understand the overall benefits and challenges that NbS bring to communities. Evaluating effects of the NbS on society, through inquiring about health, quality of life, wellbeing and community life, contributes to knowledge building and can aid in taking better decisions in the future (Kabisch et al., 2016). Continuous monitoring of NbS and research on their benefits, challenges and effectiveness is needed both to sustain further development of NbS and to ensure continuous success and access to NbS positive impacts on societal wellbeing and health, stress and depression reduction, and environment (Kabisch et al., 2016; Kolokotsa et al., 2020).With growing literature on frameworks and indicators for assessing NbS (Kabisch et al., 2016; Raymond et al., 2017; Raymond et al., 2017b), there are few studies utilizing these frameworks. For this reason, this literature review chapter will not include examples of studies similar to mine, rather it will focus on literature discussing general social impact of NbS, Assessment Frameworks and Methodologies, Health and Wellbeing in connection to NbS, citizens perception on NbS, and Economic efficiency of NbS.

2.1 Nature-based Solutions and Social Impact

NbS, when incorporated into urban landscapes alongside green spaces like parks, show a capacity to enhance the mental and physical health and overall wellbeing of citizens (Van den Bosch & Sang, 2017). Research underlines nature's effectiveness in mitigating heat levels and improving mood, among other benefits. These factors correlate with reductions in cardiovascular disease-related mortality, all-cause mortality, and the prevalence of mental disorders. Van den Bosch and Sang (2017) comprehensive review of reviews, which focused on the nexus between the natural environment and public health, particularly emphasize socio-behavioural ecosystem services (e.g., physical activity) and their interconnection with regulating ecosystem services (e.g., water retention), provides strong evidence. Their summary of research underscores the positive impact that the integration of NbS into urban settings can have on societal health and wellbeing (Van den Bosch & Sang, 2017). As this and other reviews suggest, there is a large body of literature discussing health benefits and health related impacts of nature, urban greenery or NbS (Kolokotsa et al., 2020; Lee & Maheswaran, 2011; Tzoulas et al., 2007). For this reason, I find referring to a comprehensive review fitting for this literature review.
Van den Bosch and Sang (2017) review, although arguing for potential health benefits of nature, focuses on studies assessing nature's impact on people, not NbS's impact on people. While that is understandable, I believe it should be clarified what types or sizes of NbS the authors are referring to, since as discussed in the beginning of this thesis, NbS cases vary extremely in their type, and size. I believe it is wrong to use the NbS concept as an umbrella here and assume similar health benefits from a park which includes many NbS within its design to a small NbS drainage.

Other works focus on NbS impacts beyond health and wellbeing. These entail societal and environmental aspects, such as gentrification, justice and climate resilience (Bayulken et al., 2021; Bockarjova et al., 2020; Mabon et al., 2022). I will focus on gentrification as I believe it is relevant in the light of the transformation of the studied area over the last decades. In a conversation with a local community development organization, Ila Velfrorening, I have learnt that generally speaking the neighbourhood and its attractiveness changed considerably since the 1990's (Ila Velforening, personal communication, April 24, 2024).

Green interventions and creating urban nature have a positive impact on property prices in cities as they add value (Bockarjova et al., 2020). Gentrification and social injustice can be an unwanted (for the residents) outcome of implementing ecosystem services and urban greenery into the urban environment. This is well demonstrated by Bockarjova et al. (2020) who conducted a meta-analysis of pricing trends based on 37 primary hedonic pricing[1] studies.
Their analysis of the European model shows that moving 100m closer to an urban park or urban forest results in price increases of 1,82% and 2,06%. Similarly moving closer to a blue nature increases the price of housing by 0,47%. The authors argue that green urban renewal or green interventions in the city could therefore lead to displacement of lower-income residents of the area by wealthier residents. The study shows potential negative, unwanted impacts of NbS on residents of area in which they are implemented (Bockarjova et al., 2020). I believe this point shouldn't be forgotten during discussions on urban greening. It is important to improve the city, but with a consciousness of for whom.

On the other hand, NbS worldwide enhance sustainable urbanization and ecosystem restoration and by doing so improve communities' resilience and develop mitigation and adaptation strategies to climate change. By improving or aiding urban and peri-urban environment through NbS not only residents' health and wellbeing is affected. It is also their safety and resilience in terms of climate change and extreme weather events coming with it (Bayulken et al., 2021).

Lafortezza et al. (2018) collected studies focusing on NbS in connection to ecosystem resilience, urban environments and sustainability in built environments. The examples showcased successful NbS cases, of different scales from around the world. The paper includes key lessons from each study. The multi-challenge approach has been highlighted by the authors. They argue for planning NbS for multiple challenges, and for including stakeholders in this process. They also underline the need to assess NbS impacts across scales, adapting NbS for these scales and their specific context. Finally, lessons from successful case studies revolve around establishing strong bottom-up partnerships, as it proved central to successful implementation of NbS. The body of literature on the topic is

[1] Hedonic pricing method is used to measure the effect environmental features have on the property prices (Bockarjova et al., 2020).

vast, as Lafortezza et al. (2018) underline, and there is a lesson to be learned from successful and unsuccessful NbS.

Key studies related to the societal impacts of NbS discussed above focus mainly on the benefits for the inhabitants of a given area or for the environment in which NbS has been implemented. The concept of NbS as discussed earlier has been created to deliver solutions to societal and environmental challenges as well as to ensure benefit of both people and environment therefore the studies seem adequate. However as exemplified by Bockarjova et al. (2020), NbS do carry potential trade-offs to urban dwellers. Perhaps more studies on planning, mistakes, NbS failures and NbS-caused gentrification could be conducted.

2.2 Frameworks and Assessment Methodologies

Increasing research and awareness on NbS and its climate change mitigation role, adapting for challenges in NbS implementation and socio-environmental justice consideration when implementing NbS have been identified by Kabisch et al. (2016) as main needs in ongoing research and policy agendas dealing with NbS. Group of experts from Geography, Ecology, Municipalities and society has identified these challenges during an inter-transdisciplinary workshop on “Nature-based solutions to climate change mitigation and adaptation in urban areas” which took place in Germany in 2015 and was a part of a research project with the same title. The goal of the research project was to showcase good NbS practices, identify indicators measuring NbS success and lastly to identify and address knowledge gaps in the NbS field. These objectives were addressed during the workshop, as experts identified knowledge gaps and indicators for measuring NbS effectiveness and its benefits (Kabisch et al., 2016). These indicators and the examples of methods to measure them were the starting point in developing the methodology that I used for my thesis research (see chapter 4). Kabisch et al. (2016) argued for integrated environmental performance, health and wellbeing, transferability and monitoring and citizen’s involvement as the indicators that would aid in measuring NbS effectiveness and its potential co-benefits. Each of these indicators was in their study followed by a few examples of how they could be assessed. As stated above Kabisch et al. (2016) suggest future research, knowledge gaps and examples of indicators that provides the baseline and information necessary to begin working on assessment of a given NbS case.

Following the groundwork laid out for the topic of assessing NbS, I will now introduce related works. A NbS created for a specific issue within the city, most likely will produce additional benefits, (referred to as co-benefits). Based on a review of over 1700 scientific and practical documents covering most relevant societal challenges for cities worldwide, Raymond et al. (2017b) developed a framework for designing and implementing NbS and for assessing the co-benefits and costs of NbS. The framework is supposed to work across different cultures, ecosystems and climates and includes four dimensions based on the Kabisch et al. (2016) workshop: co-benefits for human life and wellbeing, integrated environmental performance, trade-offs and synergies to biodiversity, health or economy, and potential for citizens involvement in governance and monitoring. Raymond et al. (2017b) argue that the last step of the framework, which is managing, maintaining, monitoring and assessing NbS over long time, needs to be a part of the framework from the very beginning. This step is needed to track changes in NbS impact, assess how the NbS responds to the challenge it was created for, to create better solutions in the future, and to take advantage of all possible co-benefits (Raymond et al., 2017b). The authors provide resources and examples for approaches to all the steps, from identifying the need for NbS to monitoring. A lot of attention is given to the co-benefits, the reason for that is the previous lack of frameworks addressing and assessing these additional benefits that should be considered when working with NbS. The authors point out a knowledge gap and an absence of tools that could simplify and systematize monitoring and evaluation of co-benefits, which would support taking informed decisions.

Building on the insights from these studies I will now move on to the final comprehensive framework which guided and inspired me in approaching my assessment of Iladalen Park. Eklipse Expert Working Group report is a framework for impact evaluation to support planning and evaluation of NbS projects, funded by the European Union Funding- Horizon 2020 (Raymond et al., 2017). The report covers three objectives: 1) developing an impact evaluation framework, 2) preparing application guide, and 3) making recommendations to improve existing assessments of the NbS projects effectiveness. In short, the Eklipse Working Group prepared the framework at the request of the European Commission to help build evidence and knowledge base. The report can be utilized in an academic manner but essentially it is a tool allowing for planning and carrying out a successful assessment of a given NbS project. The document works also as a source- the report provides additional

sources for all the indicators, methodologies, instruments to use and case examples.

However what the Eklipse framework, similarly to Kabisch et al. (2016) and Raymond et al. (2017b), doesn't provide is a metric scale or threshold suggestion of any sort that would guide the outcomes of measuring the indicators. I believe that it is a serious shortcoming as it poses a barrier in carrying out the assessment. For the lack of suggested desirable outcomes of the indicators essentially leaves a person carrying out the assessment with an arbitrary number or answer. For the lack of common metric scale or a threshold I was forced to simplify the outcomes of indicators. I will discuss this in detail in the methodology chapter (see Chapter 4), however the point is that an assessment without a key is not ready to use.
Eklipse framework addresses this issue very shortly arguing that:

> A large variety of thresholds for specific indicators are present in the legislation and regulations at various spatial and administrative scales. Thresholds related to NBS efficiency should be considered in relation to the local context, which is better suited for defining them, especially when no legal standards exist. From the perspective of adaptive strategies, the definition of "critical thresholds" with respect to key indicators can help identify situations in which changes in the design of NBS or new solutions are needed (Raymond et al., 2017, p. 47).

While I understand that providing a general scale would be inaccurate, I believe that in the spirit of the whole report the authors should suggest more sources and discuss this crucial part of the assessment more thoroughly.

Moving on, Kabisch et al. (2016) and Raymond et al. (2017b) provide very general frames which require much further work to implement them in concrete studies, whereas the Eklipse report guides you through all necessary steps except for the mentioned shortcoming in thresholds and final outcomes (Raymond et al., 2017). Eklipse provides indicators, suggested methods, instruments, and software for their measurement together with a long list of additional sources. It addresses the scale and relevance of suggested indicators. However, all three papers essentially provide the reader with few umbrella terms, suggesting multiple indicators assessing different aspects falling under the topic umbrella. All three papers also suggest highly multi-disciplinary assessment frameworks, which if utilized could allow for creating a very well-rounded image of NbS impact. All three papers pay attention to the

environmental aspect for which the solution has been implemented, they all entertain economic efficiency in some way, they all discuss participation and citizens role as well as health, wellbeing and quality of life.

2.3 Perception

Kabisch et al. (2016) emphasize the importance of citizen participation in urban planning and in decision-making processes. Participation is considered crucial for successful co-management between the stakeholders and city administrations. For this process, and for successful implementation, citizens support and positive perception on greening and NbS efforts is necessary. Hadavi et al. (2018) suggest that residents positive perception of urban greenery can in return be beneficial for the citizens themselves, as it makes them more likely to use these spaces, which in return can enhance their wellbeing. Kabisch et al. (2016) and Raymond et al. (2017) include assessment of citizens participation and citizens perception on NbS projects. So how do citizens perceive NbS?

Based on a Portuguese case study by Ferreira et al. (2021), most expected by citizens benefits of NbS include creation of leisure and relaxation space, air purification and temperature reduction. Most citizens preferred type of NbS was urban trees. Ferreira et al. (2021) assessed perception of urban challenges, expected NbS benefits and preferences between types of solutions through stakeholder’s interviews. Stakeholders interviewed in Elvas and Faro covered a range of positions, from policymakers to citizens. By approaching various stakeholders, the study aimed to emphasize the importance of understanding their perception, expertise, and preferences in successful implementation of NbS. The stakeholders were also asked which of the identified urban challenges should be prioritized (Ferreira et al., 2021). This type of localized knowledge is necessary for the implementation to be relevant and successful. This study on stakeholders' perception of NbS shows that citizens within their opinions and localized knowledge hold valuable information for NbS design and urban planning (Ferreira et al., 2021). Perhaps one thing missing from the article to give a well-rounded picture of citizens' perception could be their opinion and perception on already existing NbS. In fact, very little research has been done on small scale public opinions on existing NbS. Focus has been on NbS challenges, impact assessments and opinions on NbS to be created in future (Shen & Wang, 2023).

2.4 Economic Efficiency

Similarly to the previous paragraph, Economic efficiency or economic aspects of NbS have been included in all three framework papers discussed above (Kabisch et al., 2016; Raymond et al., 2017; Raymond et al., 2017b). Raymond et al. (2017) specifically suggest utilizing analysis of cost-effectiveness and cost- benefit in NbS assessment. Cost-benefit relationships vary across different conditions. For example, green roofs and green facades, as a high-cost investment show negative relationship- costs exceed the benefits. However other solutions such as retention ponds, urban gardens, roadside trees provide benefits higher than the costs. This study has been done by Biasin et al. (2023) in Turin, Italy. The objective was to analyse the contribution of selected different types of NbS in improving resilience to climate change, with a focus on urban heat island and urban floods. After identifying areas under climate risks and selecting NbS for the study, Biasin et al. (2023) developed four scenarios. Each scenario entails a different number and combination of NbS. Creating four different scenarios for analysis allowed for a comparison of different land use and aid in informed decision-making. The four scenarios were then applied into InVEST® models which allow for comparison of costs and benefits associated with implementation of these cases. The study suggests that extensive application of the NbS which costs exceed benefits such as the green roofs and facades is cost ineffective. Instead, they suggest utilizing these solutions in a targeted and specific manner. The study recognized the synergies and co-benefits provided by NbS, which increase the value of the economic services they provide. Biasin et al. (2023) propose integrating NbS and grey infrastructure, as well as Implementing NbS in already existing green spaces to maximize the benefits. The aim of the article was to aid in implementing efficient policies enhancing urban climate resilience.

The InVEST model can be used in future by other actors interested in carrying out a comprehensive cost-benefit analysis. The results showcase the economic efficiency of NbS, which could be useful for public opinion. Nonetheless, I think it is relevant to mention the criticism towards ecosystem services. As discussed further, in the theory chapter (see Chapter 3), putting a price tag on services delivered by nature is challenging. Some argue that the limitless value of nature is undermined by quantifying it, others argue about the methods. It is only to say that the economic value of services delivered by nature, and with that by NbS are an estimate (Costanza et al., 2017). My personal reflection here, and something that could be

discussed or studied further is that perhaps ecosystem services value inflates when climate change intensifies, and extreme weather events become regular.

2.5 Challenges and Gaps in the Literature

Authors of the literature discussed above have identified many research gaps in the relatively new field of NbS. In fact, one of the main objectives for Kabisch et al. (2016) was to define knowledge gaps related to NbS for climate change adaptation and mitigation in urban areas. They include effectiveness of NbS in connection to insufficient knowledge on trade-offs and synergies between NbS and biodiversity, human health and other societal aspects. The relationship between NbS and society, the impact that NbS can have on life quality, beliefs, gentrification etc. There is also little knowledge on designing NbS in multifunctional urban planning[2]. Kabisch et al. (2016) address lack of knowledge on implementation aspects. Raymond et al. (2017b) argue as mentioned before, that more systematic monitoring and evaluation after implementation is needed to learn just how effective are NbS in practice, and how can they be improved. They also argue that monitoring and evaluation will aid in understanding trade-offs and co-benefits which will lead to a holistic understanding of the social impact of NbS. Lastly Eklipse framework provides the reader with a two-page long list of knowledge gaps related to the assessment of NbS impacts. Sixteen gaps fall into four areas requiring more research: actions and impacts, indicators, methods and governance, communication and engagement (Raymond et al., 2017). Methodology used in these papers, precisely the frameworks (Kabisch et al., 2016; Raymond et al., 2017; Raymond et al., 2017b), InVEST model for cost-benefit analysis (Biasin et al., 2023), and Hedonic pricing meta-analysis for assessing gentrification (Bockarjova et al., 2020) deliver a solid basis for future, bigger scale analysis of NbS impact on municipality or city level.

In summary, the reviewed literature has provided this thesis with significant contributions from the last two decades. I attempted to provide background to all the aspects I utilized or will be inquiring about in my research. These aspects being: NbS social impact (including wellbeing and quality of life improvements), existing NbS assessment frameworks inquiring

[2] Multifunctionality is a very relevant aspect of NbS in urban areas, and it means that multiple functions of NbS (ecological, social or economic) shouldn't be random additional benefits. Multifunctional urban planning of NbS means deliberate planning for fulfilling multiple social, ecological and economic functions (Hansen & Pauleit, 2014).

about social impact and co-benefits, citizens perception on NbS and NbS economic efficiency. In subsequent chapters I build upon the background work presented in this chapter. I combine approaches and suggestions from the three discussed frameworks (Kabisch et al., 2016; Raymond et al., 2017; Raymond et al., 2017b), and attempt on answering the research gap identified by Raymond et al. (2017b) by re-visiting existing NbS, evaluating its impact so far and asking stakeholder for their opinion. My research will therefore add on to the topics discussed above, and contribute with small scale case study, providing nuanced localized knowledge.

3 Theoretical framework

This chapter's goal is to present the theoretical framework which guided this research's empirical work. Multiple concepts will be presented and discussed in the context of assessing the social impacts of a NbS case. Firstly, theory of social-ecological systems (SES) will be presented, serving as a rationale and as a conceptual framework behind the research. Second, the concept of human wellbeing and approaches to it will be discussed, and its meaning in this thesis will be defined in connection to place. Third, Wilson's (1984) Biophilia theory will be discussed in connection with the concept of human wellbeing and SES. Finally, the theoretical framework in this thesis includes the concept of ecosystem services, which will serve as a basis for one of the assessment's indicators.

3.1 Social-ecological systems theory

SES is a theory first formulated in 1998 by Berkes Folke. As the name suggests, the theory connects social systems with ecological systems. The former refers to property, land and resource rights and systems, environment knowledge systems, and to the discourse and ethics around the environment and resources. Ecological systems refer essentially to the ecosystem, the nature. The authors argue that a delinking of these two systems is unnatural (Berkes & Folke, 1998). I agree with this approach and believe that work and research on urban greenery (including my own thesis) would benefit if done from such point of view. Humans and their social systems were traditionally viewed as external to ecosystems, in biological ecology. Some approaches within bioecology even treated humans as disturbance factors. Other biologist argued for considering humans as a part of ecosystem. Through efforts from applied ecology, anthropology and archaeology among others, humans were overtime included in ecosystem analysis and recognized as ecological entities with multidimensional environments (Pavao-Zuckerman, 2000). Berkes and Folke (1998) consider humans and their social systems to be a part of the ecosystem, referring to, the traditional and indigenous societies and their relationship with the environment, among other things.

SES theory was developed to understand the social dimensions of environment management and to contribute towards sustainability and resilience governance. Researching SES requires

interdisciplinary, international research, and is often based on case studies (Berkes & Folke, 1998). Case studies help in identifying structural characteristics within given SES, contributing to a better understanding of their dynamics and presenting clear linkages between social dynamics and ecosystem changes (Behnassi et al., 2021, pp. 255-256; Janssen et al., 2006). Since 1998 the SES theory has gained popularity and its initial framework; the SES approach evolves (Janssen, 2011). Janssen et al. (2006) for example, take a network approach when working with SES, defining the SES as a network of nodes and links representing the system itself, together with other entities within that system. They underline the interconnectedness between these entities and the flow of information and materials that move between them (Janssen et al., 2006).

SES and frameworks following the theory will not be used directly in this assessment of Iladalen Park. However, I find it useful to present a conceptual background in which I study and perceive the relationship between the Iladalen Park and the local society. The theory defines my position in assessing urban environment. Iladalen Park as an NbS case is perceived in this thesis as a part of urban nature, part of ecosystem, whereas the population of the studied area, is the social system within this approach. In other words, I consider the NbS and local population as interconnected.

3.2 Wellbeing

As I utilize the concept of wellbeing in my research it is necessary to discuss approaches to it and attempt to choose a definition. Measuring and studying wellbeing and happiness have gained popularity since the 1960's. Assessing happiness and wellbeing is often used as an answer, and recognition to the shortcomings of other ways of measuring progress and social development, such as Gross Domestic Product (GDP). GDP, as a measurement of social development, is criticized by many for its lack of appropriate presentation of inequality (Smith & Reid, 2018). It is argued that as a measurement of economic growth it is fundamentally a capitalist measurement, which completely discounts environmental sustainability and social aspects of development (Adams, 2020, p. 104). In fact, macro-time studies (10 years or more) show no relationship between income and happiness, as happiness and wellbeing become subjective after a certain threshold of income (Smith & Reid, 2018). Interest in big scale quantitative studies on wellbeing and happiness became widespread in recent decades. Indicators of happiness in given cities, such as the "Happy Planet Index" or

the concept of Gross National Happiness in Bhutan, are examples of the growing popularity of such studies and approach (Smith & Reid, 2018).

I view and use wellbeing as a concept in my research following the approaches presented by Scott (2012), Smith and Reid (2018), Haybron (2011) and Atkinson (2017). Their studies introduced the vision of wellbeing as a dynamic, contextual process, influenced by many factors that change in space and time, such as (but not limited to) social relationships, culture and environment. I will discuss and present their works below.

Geographers have had a significant role in wellbeing studies as they shed light on the connection between subjective wellbeing and the myriad of factors in the human environment. They improved the understanding of relations between health (beyond disease) and place, laying foundation for geographical studies focusing primarily on wellbeing since 2000's (Atkinson, 2017). In Geography, in wellbeing studies, the main philosophical distinction for scholars is the one between the eudemonic and hedonic approach to wellbeing and happiness. Hedonic wellbeing as the name might suggest is based on pleasure, and can be obtained physically, whereas eudemonic wellbeing revolves around fulfilment and meaning (Atkinson, 2017). Smith and Reid (2018), argue that both traditions overfocus on the individual experience of wellbeing, potentially overlooking social and environmental factors. Regardless of the philosophical approach taken, contemporary studies within geography address wellbeing on an individual level (Atkinson, 2017). As an outcome of these studies, many lists of factors that add up to wellbeing, or influence wellbeing have been created. They include relevant factors such as income, social relationships and health. Breaking down the complex concept of wellbeing into components and factors allows for measurement and research (Atkinson, 2017).

With that said, there is no single academically recognized and agreed upon definition of wellbeing. Both the definition, and factors influencing it vary vastly across time, space and most importantly cultures (Atkinson, 2017). Some geographers therefore suggest a broader definition, which would include both local context, and universal components such as social relationships, health, or income (Atkinson, 2017). However, Scott (2012, p. 16) argues that any theorisation on wellbeing is directly connected to a specific theory on the meaning of life and meaning of being human. Different takes on what wellbeing means are therefore based on social and cultural values in connection to the meaning of life, meaning of relationships,

even meaning of one's role in society (Atkinson, 2017).

Another very important, recognized and studied aspect of wellbeing is the contextual perception or experience of wellbeing. Studies show that self-reported wellbeing will fluctuate depending on the circumstances of a given day. For example, self-reported wellbeing comes out higher on sunny days (Smith & Reid, 2018). Similarly, location and more specifically the environment matter, shaping our activities, perspectives and feelings. This, like previously mentioned limitations, makes quantifying self-reported wellbeing challenging. A fitting approach could therefore be to see wellbeing as a process, rather than a state (Smith & Reid, 2018). Viewing wellbeing as dynamic, however more appropriate, doesn't make the research on wellbeing, or defining it, easier. Lack of clear-cut definition of studied concept could become a limitation, or a source of confusion.

Some geographers work on qualitative approaches that would go around such limitations in studies (Andrews et al., 2014; White, 2016, 2017). Smith and Reid (2018) point out that any approach to studying wellbeing will pose limitations however most of the current approaches share one biggest limitation- lack of ability to consistently consider the context and setting of the wellbeing. For this reason Smith and Reid (2018) analysed approaches, which try to include the context and relationships with and within the living environment- thus they attempt to go around these limitations. Based on these, Smith and Reid (2018) proposed reconceptualised approach to studying wellbeing named "intra-active wellbeing". Their goal is to understand wellbeing as a dynamic phenomenon arising from environment, and emphasizing the relations between human and non-human in shaping wellbeing (Smith & Reid, 2018).

Studies show that greenery in our environment can have a considerable impact on our wellbeing and quality of life (Haybron, 2011). Green environment benefits individuals but it can also enhance the social life of a neighbourhood. In a big study on inhabitants of green and grey areas in Manhattan (New York city, US), assessing contact with nature and effect it has on urban dwellers, the inhabitants living in green areas of Manhattan, had better social ties and relationships with their neighbours (Haybron, 2011). They were also less likely to be aggressive towards their partners compared to the inhabitants of the grey areas. This matters in the context of wellbeing as scientists agree that human relationships and community are

the biggest source of happiness (Haybron, 2011).

Then there are as well more physical and psychological aspects connecting greenery with health benefits associated with wellbeing such as stress reduction. Various experimental studies show that contact with greenery (through viewing or spending time in greenery) can have a positive impact on one's health, such as decreasing anxiety, decreasing stress, lowering blood pressure and improving cognitive functioning (Haybron, 2011). This will be discussed further in the subchapter 3.3.

Above I have discussed approaches to wellbeing, underlined the challenge of defining the concept and explained how I approach wellbeing in my research. Based on that I utilize wellbeing as one of the indicators to assess the social impact of Iladalen Park. Therefore, the wellbeing of the inhabitants of the studied area won't be studied in a vacuum. It will be studied in the context and in a clear connection to the Iladalen Park. Wellbeing, for the purpose of the indicator in this study, will be directly assessed through a survey. Therefore, the perception of wellbeing will be self-reported by the participants. This means I do not have complete control and influence over how the participants understand wellbeing and how they report it the day they participate in the survey. I do ask about the wellbeing in a connection to the Iladalen Park, and I have built the survey in a manner that I hope will allow the participants to keep the park in mind and not get, influenced by the context bias mentioned earlier (see Chapter 4).

3.3 Biophilia hypothesis

Conceptualized by Wilson in "Biophilia, the human bond with other species" (1984), the Biophilia hypothesis argues for the existence of a deeply rooted human need to connect with nature (Kellert, 2013). According to the hypothesis, this need is based in biology, and aided our evolution as humans. The hypothesis focuses on the need for connection with nature for emotional, cognitive and aesthetic needs, but it also covers learning and adaptation. Human inherent tendency to assign value to nature and connect with living organisms is to be an outcome of our evolution. By engaging with the natural world and ecological functions such as water cycle and ecosystem, we adapted and thrived as species (Kellert, 2013). If human beings disconnect from nature, or nature is degraded, the negative consequences are to include not only the material realm, but also emotional and cognitive one. The Biophilia

hypothesis points out that human wellbeing is tightly interconnected with the surrounding natural environment (Kellert, 2013). This idea correlates with the wellbeing studies and the summary of my approach to the concept. Already in the 80's, Wilson (1984) discussed the loss of genetic diversity and species diversity, degradation of nature, and how necessary nature and its diversity are to sustain human life and human wellbeing. Research confirms human preference for the natural over the built environment, as well as the negative impact of the disconnection from nature for both human and environmental wellbeing (Mangone et al., 2017; Parsons, 1991; Ulrich, 1984).

Biophilia hypothesis in the urban context translates to Biophilic design- as a way of reconnecting with nature for urban dwellers and as an answer to the innate need to interact with nature (Amat et al., 2020). Biophilic design includes patterns of the design that could help in connecting nature with the built environment in a bigger sense and scope than simply introducing vegetation. Five main patterns of biophilic design include visual connection with nature, non-visual connection with nature, presence of water, thermal and airflow variability and non-rhythmic sensory stimuli which refers to stimulating sensory responses in an unpredictable way. In other words biophilic design includes nature in the city but also shapes the city to resemble the natural environment more closely (Amat et al., 2020).

How exactly do scientists working with Biophilia argue for its existence? Firstly, from an evolutionary perspective and evolutionary time scale, humans have only started living in villages and cities very recently. Frumkin (2001) calculated that if our entire life span as homo sapiens was 70 years, only in the last four months of the 69th year, humans started creating villages and later cities. In the evolutionary time frame, homo sapiens left the natural environment and changed well established patterns just a few months ago (Frumkin, 2001). Secondly, they argue for its existence by inquiring about wellbeing and feelings around plants. Participants of different surveys over the years clearly value green spaces highly. Frumkin (2001) brings examples of retirement home residents considering windows facing greenery as important and office employees favouring office spaces with plants over the ones without. Haybron (2011), when arguing for Biophilia's existence brings up a rather old, but famous study by Ulrich published in S*cience* in 1984. Ulrich (1984), over the 1970's carried out a study on post-operation patients, staying in suburban hospitals in Pennsylvania (USA). Patients, who were assigned a room with a view on nature left the hospital earlier than patients who were assigned a room with a view on a brick wall. Similarly, the patients whose

windows faced greenery took less painkillers and received less negatives comments in nurses' notes, opposite to matched patients staying in similar rooms, but facing the brick wall (Ulrich, 1984).

In other words, the Biophilia hypothesis argues that for humans to feel good (whether we discuss physical or psychological wellbeing), contact with nature is needed. It argues for reintroducing nature into human made environment and for conserving the environment and biodiversity. This is a relevant point of view for my research, not only for the motivation behind the aim of assessing the social impact of a nature-based solution case on local society but also specifically for designing one of the indicators (see also Chapter 4). This indicator, explained in detail in the next chapter, estimates the healthiness and density of vegetation in the Iladalen Park. After Biophilia hypothesis, and presented research backing it up, when assessing the indicator, I consider dense and healthy greenery to be of a positive impact on the local society.

3.4 Ecosystem Services

Ecosystem services are not a new concept. It has already been discussed in the 90's by scholars such as Daily (1997). She defines ecosystem services as:

> Conditions and processes through which natural ecosystems, and the species that make them up, sustain and fulfil human life. They maintain biodiversity and the production of ecosystem goods, such as seafood, forage, timber, biomass fuels, natural fiber, and many pharmaceuticals, industrial products, and their precursors (...) In addition to the production of goods, ecosystem services are the actual life-support functions, such as cleansing, recycling and renewal, and they confer many intangible aesthetics and cultural benefits as well (Daily, 1997, p. 3).

If these aspects feel like a given, Daily (1997) suggests imagining moving to the moon, and solving the issue of not having any of the life supporting processes or life supporting materials (such as the air) available freely. She then continues to list all services, provided by nature for free. Costanza et al. (1997), in their study describe the value of these services, and estimated that the direct and indirect services, contributing to the human welfare are worth between 16 to 54 trillion US dollars per year. The study maps how this economic valuation is

distributed in space, highlighting how a big part of the value delivered by the ecosystems is on the equatorial zone (Costanza et al., 2017).

These two publications (Costanza et al., 1997; Daily, 1997) from 1997 on, popularized the concept. They have been followed not only by extensive research and academic interest, but also by applications of the idea in policies (Costanza et al., 2017). The economic estimates have been met with criticism, some towards undervaluing the limitless potential and value of nature, others towards flawed approach towards quantifying monetary value of these services (Bockstael et al., 2000; Pearce, 1998). And while the challenge of putting the price on nature is real, the main point of these two publications was to "demonstrate that ecosystem services were more important to human wellbeing, than conventional economic thinking had given them credit for" (Costanza et al., 2017, p. 3). The estimate in the economic value was to deliver a comparable and understandable measurement for people. However, Costanza et al. (2017) agree that it might not be possible to have an exact estimated value, but also underline that it is not the point. The point is that nature is more valuable than its human-made alternatives. Nonetheless some argue that such an attempt of economic evaluation creates a risk to nature's sacredness (Costanza et al., 2017) pricing a service might suggest that it can be bought, or that damage to nature can be simply paid for with money.

While I recognize the downsides and critiques of such an approach to the ecosystems or nature in general, the economic evaluation is still useful in cost-benefit analysis at the local scale. Since the NbS case goal is to deliver ecosystem services, the development of an indicator that assess the economic efficiency and values of the investment/cost of the NBS is paramount. The economic efficiency indicator that I use in my study will be presented and discussed in detail in the following chapter. I aim to utilize the concept in accordance with the goal it was created for by Costanza et al. (1997) and Daily (1997), by assessing the economic efficiency but also to provide an understandable measurement of the benefits that urban nature (that could be taken for granted) delivers.

The theories and concepts discussed above share a common core focus on the human dependency and need for contact with nature. They view the disconnection of humans from nature as "unnatural", negative or as having negative consequences. They all put human welfare and wellbeing in connection to nature at their core. SES, Biophilia hypothesis and Ecosystem services have all been developed in physical scientific approaches ranging from

ecology to biology. The wellbeing studies source proof from these approaches, however presented above perspectives on wellbeing stem from human geography. My take on wellbeing, after Scott (2012), Smith and Reid (2018), Haybron (2011) and Atkinson (2017), is that wellbeing is a dynamic, contextual process, influenced by many factors that change in space and time. I find that it correlates with SES, Biophilia hypothesis and Ecosystem Services, as these concepts underline the interconnectedness of humans and nature, human wellbeing and environment.

Ecosystem services and the Biophilia hypothesis showcase two different approaches and points of views on the human dependency on nature. Ecosystem services present a very practical, evidence based and quantifiable approach, providing the readers with a list of services they are being provided with by nature “for free”. Biophilia hypothesis on the other hand, while delivering science-based profs for its aspects, focuses first on the innate human nature to argue that we as homo sapiens need nature (beyond the ecosystem services). Together these theories and concepts have been important for developing the methodological approach and analysis of the empirical work of my thesis.

4 Methodology

The following chapter presents the research strategy and the methodology. It includes a brief discussion on the framework which was designed in this thesis, as well as data analysis and assessment conducted.

Kabisch et al. (2016) research inspired my thesis work. They have identified biggest research gaps and potential indicators in the field of NbS assessment, during an expert workshop. The experts, as discussed in literature review (see Chapter 2), identified various indicators able to address the effectiveness of the NbS in relation to climate change adaptation and mitigation and their associated co-benefits. Those include human health and wellbeing, integrated environmental performance, transferability and monitoring as well as citizen's involvement.

I have carefully considered time and resource limitations which revolved around the Biology and Ecology knowledge and practical expertise needed to assess physical aspects of NbS. I don't possess the expertise to assess the physical impact of Iladalen Park such as detention pond performance, water storage, infiltration or stream biodiversity changes. More importantly however Trondheim Municipality carries out annual monitoring of water quality and environmental condition including diverse set of analysis in the waterbodies, rivers and streams in the municipality (Trondheim Kommune, 2023). There is no information on such assessment specifically done for the NbS and their performance, yet considering my lack of expertise in that field, the knowledge I would create would not fill any gap. I have then decided to focus only on the social aspect of the impact that Iladalen Park, as a NbS case, has on the citizens living in the area.
However, as already pointed out by the Universitetskommunen employee whom I talked to, Trondheim Municipality doesn't currently have a way to present the benefits of the implemented NbS to the citizens (Universitetskommunen Trondheim, personal communication, November 10, 2023). Citizen's acceptance and support in greening initiatives is argued to be essential in successful urban greening strategies (Raymond et al., 2017b). Therefore, with my research I want to contribute to filling knowledge and research gaps, but I

also want to design a framework that could be used by Trondheim Municipality to inform the citizens about NbS and the impact they have on local communities. Raymond et al. (2017); Raymond et al. (2017b), and Buchel and Frantzeskaki (2015) works influenced the final design of the indicators suggested by Kabisch et al. (2016) as well as the tools and instruments selected for this study. This work contributes by selecting and adjusting the indicators suggested in the literature to match the local context and scale, as well as creating a final metric for assessing whether the outcomes of the implemented NbS generate a positive, negative or neutral impact on the local population.

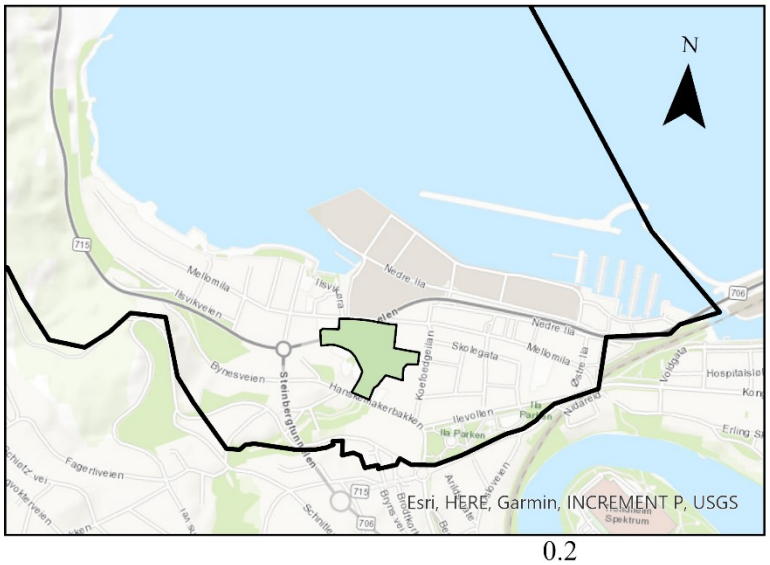
4.1 Research Design

As already mentioned, the NbS developed in Trondheim have not been assessed in terms of social impact and effectiveness since their creation. The limited time I had at my disposal for developing this thesis research required me to choose and focus on one case only. Therefore, this research is designed as a case study, focusing on a singular case of a Nature-based Solution in Trondheim, Norway. Research that uses case study usually focuses on a single unit of specific phenomena to improve and expand the knowledge on the larger group of similar phenomena and to explore nuances and the influence of the context (Baxter, 2021). NbS cases vary vastly given their scales, environments and goal, therefore their assessments would vary vastly (World Bank, 2021). However, as Raymond et al. (2017b) pointed out in their work, even unsuccessful cases can lead to developing better solutions and considering more aspects in the future. While this study is not generalizable, it is replicable. The defined indicators allow for replicability on NbS cases of similar size and characteristics.

4.2 Population and case study sample

The citizens living around the Iladalen park have been involved in this research through a survey meant to assess their perception and wellbeing in connection with the Park and NbS developed within it. The survey has been built to mainly target the adult residents (above 18-years old) of the Ilsvika and Skansen neighbourhoods (see Map 1, page 37), corresponding to the postcode 7018 (Geodata Online, 2023). The shape of the study area is irregular, and it measures roughly 1.200 meters long and 400 meters wide. The neighbourhood borders Mitbyen- the city centre. According to Geo Norge in the two neighbourhoods of Ilsvika and Skansen live around 2.920 people (Geodata Online, 2023).

Map 1. Urbanized area of Trondheim with postal code 7018



To overcome language barrier issues and due to time limitation, the survey was shared online both in English and Norwegian through the neighbourhoods' social media groups (Facebook) and through the network of neighbourhood's community development organization- named Ila Velforening. I will mention here that after receiving survey results, I had a meeting with Ila Velforening to ask few background context questions about the neighbourhood and the community life. Ila Velforening consists of neighbourhood residents and deal with local environment, regulatory plans, hearings and maintaining Ila as a diverse neighbourhood with good living environment (Ila Velforening, personal communication, April 24, 2024).

As the online survey is a part of a mixed-method approach, and not a means to generate a generalizable claim about the population's opinion about NbS, the sampling for this research is a non-probability sampling (McGuirk & O'Neil, 2021). This means that making claims about the social impacts of NbS in general is not possible but will help in developing a framework that could be further tested and applied to similar NbS elsewhere. Local inhabitants' opinion on urban greenery and their impacts on their life can be context specific, varying between different urban green spaces (Harris, 2018). This survey, outside of being aimed at adult inhabitants of the area around Iladalen Park, was a self-selected survey, which

means that anyone who consented to participate could fill out the survey and become part of the sample (McGuirk & O'Neil, 2021). The survey has been created and opened on Nettskjema (University of Oslo, 2024) for 27 days – from 25th February 2024 to 22nd March 2024, and has been filled out by 56 participants, which corresponds to 1,9% of the population living in the study area.
In terms of data management, the submitted surveys were submitted anonymously- I do not have any contact information of the participants. Nonetheless, the answers are stored online on Nettskjema, which is password protected and not publicly available. The data will be deleted from Nettskjema on the June 30th, 2024.

The information needed to build the economic indicator and the necessary background information about Ila and Iladalen Park, were gathered via email sent to public entities which included City's operation department (Bydrift Trondheim, personal communication, February 12, 2024) different employees within City's engineering department (Kommunalteknikk, personal communication, April 8&12, 2024) and Ila Velforening (Ila Velforening, personal communication, April 24, 2024). I contacted city's departments inquiring first about the costs of maintenance and then about the cost of the investment into Iladalen Park. I contacted Ila Velforening to obtain context information about Ila as a neighbourhood. Later in a conversation with them I inquired about neighbourhood's past, the changes that took place over the years, the community life and events, in order to get the full context of the neighbourhood. These emails are stored on my NTNU email until June 30th, 2024, as well.

4.3 Indicator I: Perception and Impact

The health and wellbeing indicators, as suggested by Kabisch et al. (2016), include impacts on quality of life, happiness and employment. Raymond et al. (2017) in their NbS impact evaluation framework, suggested similar indicators to the ones suggested by Kabisch et al. (2016) and included studying citizens perception on urban nature. They suggest that perception should be used as the indicators able to assess participatory planning and governance impacts. Participatory processes and approaches in urban and environmental governance are claimed to be crucial for success, and the role of local actors could be helpful and beneficial in reaching and steering for the goal of given project investment (Raymond et al., 2017). Residents' perception will thus indicate further how successful the project is.

Moreover, positive perception indicates that the residents are more likely to use it and experience the benefits of urban greenery (Hadavi et al., 2018).

Raymond et al. (2017) framework includes examples of methods for assessing the developed indicators. The framework includes a wellbeing chapter, with indicators similar to Kabisch et al. (2016). Survey and self-assessment are the methods suggested in the framework for the assessment of both the perception and wellbeing (Raymond et al., 2017). In fact, many studies that investigate user perception of urban nature, emotional and social benefits, satisfaction with parks are carried out using surveys (Buchel & Frantzeskaki, 2015). For this reason, I decided to merge these aspects, and inquire about perception on the defined area of urban nature, and its potential impact on participants wellbeing and quality of life preparing my own survey (Kabisch et al., 2016; Raymond et al., 2017).

The survey consists of ten questions and three sub-questions, including yes/no, indicating opinion on a scale, multiple choice and two open questions (see Appendix 1). To utilize the data gathered through indicators for the final assessment, I developed a common weight scale, which will be explained after introducing the indicators.

Although, in a limited form and on a limited scale, including citizens' views and opinions about urban nature and its impact on their life is a crucial part of this assessment. This indicator adds human aspect to the data triangulation, as the other two indicators include only data analysis. Additionally, as emphasized on multiple occasions before, citizens' participation and acceptance are important for the success of NbS, as they contribute to the development of more effective solutions and encourage their uptake, ultimately benefiting people's wellbeing (Giordano et al., 2020).

4.4 Indicator II: Health and wellbeing

In the chapter dedicated to health and wellbeing in the Eklipse framework, Raymond et al. (2017) suggest a range of geographical indicators: NDVI, proximity measures and percentage of green space. Initially I planned to generate and utilize these three geographical indicators, however big changes in the land use of the neighbourhood happening around the same time as Iladalen Park creation in 2006 made proximity measures and percentage of green space irrelevant (Statens Kartverk, n.d.). I planned to assess both aspects before and after the park

creation, but due to big changes in the neighbourhood considering these aspects would be inaccurate. With that said I decided to continue calculating only the NDVI, following the Eklipse framework (Raymond et al., 2017).

NDVI is an index that allows for measuring and quantifying health or density of vegetation (Pettorelli et al., 2005). It analyses greenness through a contrast between two raster bands: the bands present chlorophyll pigmentation absorption (red band- RED) and reflectivity of plant material (near-infra red band- NIR). The index is the result of the ratio between the amounts of red light reflected by the vegetation and the near-infra red light captured by the satellite. The outcome of the formula NDVI=(NIR-RED)/(NIR+RED) ranges from –1 to +1. Negative outcome means lack of vegetation, whereas positive results indicate good health of studied vegetation (Arc GIS Pro, n.d.; Pettorelli et al., 2005). For this indicator, I have calculated the NDVI of the Iladalen Park, using Landsat satellite images before and after the development of the park. Positive change of the NDVI index from before to after NbS creation will mean positive outcome of the indicator as it indicates improved health of vegetation and increased greenery. No change will respectively mean neutral outcome of the indicator, whereas negative change overtime will have a negative impact on the outcome of the assessment.

I decided to work with Landsat satellite pictures dataset as it is the only satellite delivering images from before the construction of the Iladalen Park in 2006 (Wulder et al., 2022), with a resolution that's high enough for the NDVI analysis. This decision is also based on the fact that Sentinel images, which have a higher resolution, date back only to 2014 (European Space Agency, n.d.). For this analysis, I used Landsat 5 satellite to cover the period before the park's creation, and Landsat 8 for after. Initially I also tried images from Landsat 7, but they were not good enough in terms of cloudless pictures over multiple summer periods.
I used Google Earth Engine Code Editor to create summer composites (a set of multiple images- representing a period of time, instead of individual picture from one day), for summer 2004 and summer 2023 (Gorelick et al., 2017). I chose 2004 as in 2005 the construction works on the road in the park area were already began, thus creating potential bias for the NDVI index measure (Statens Kartverk, n.d.). Additionally, from 2005 on, although the park was not under construction yet, the E6 road that runs below the park and areas around were under construction, affecting the images throughout 2005-2010 (Statens Kartverk, n.d.).

I identified summer periods in 2004 and 2023 based on data from Norwegian Centre for Climate Services (Norwegian Centre for Climate Services, n.d.). On their website I analysed the temperature graphs for discussed years and chose periods during which the temperature didn't fall below 5 degrees Celsius, as temperatures consistently above that threshold indicate favourable conditions for many ecological processes (Rannie, 1986). To strengthen the indicator, I identified summer periods from 1999 until 2004 and from 2018 and 2023 based on the same criteria and ran the analysis on these summer periods as well. To summarize, the summer composites are based on the dates from Norwegian Centre for Climate Services presented in the Table 1 (Norwegian Centre for Climate Services, n.d.).

Table 1. Studied summer period dates.

Before		After	
Year	Summer period	Year	Summer period
1999	June 25th – August 8th	2018	June 7th – August 26th
2000	June 17th – September 4th	2019	June 2nd – September 2nd
2001	June 17th – September 4th	2020	June 8th – August 27th
2002	May 20th – September 19th	2021	May 23d – August 23d
2003	June 18th – September 1st	2022	June 19th – September 6th
2004	June 18th – August 24th	2023	June 4th – September 12th

I further filtered the images from these periods through scaling factors and cloud masking function to enhance data quality and accuracy by removing cloud shadows and clouds. Following, a median value[3] has been computed for each 30m x 30m (Landsat resolution) pixel for each date resulting in representative images of the summer periods.
The median allows for better analysis- otherwise I would be analysing the NDVI change based on two random dates which would not be representative of an actual NDVI in the given vegetation period. Based on these representative pictures, I calculated the NDVI. For the full code used in Google Earth Engine to obtain the results see Appendix 3. Lastly, for the final visualization of the results (see Maps 3 and 4) I used ArcGIS (Esri, 2023).

Together with the efforts described above, it is necessary to mention the limitations. These

[3] Median of pixel value across all bands for given dates.

include varying amount of cloudless satellite pictures available between seasons and other potential biases that could affect the NDVI values, such as plants architectural arrangement, height, composition of species, leaf properties and recent environmental changes (such as intense rainfall or drought) (Pettorelli et al., 2005).

As discussed in the theory and literature review chapters (see Chapter 2 and 3), it is argued that healthy greenery has a positive impact on the local society. Raymond et al. (2017) when suggesting geographical indicators referred to more studies confirming this approach (De Vries et al., 2003; Kabisch & Haase, 2014; Maas et al., 2006; Van den Berg et al., 2010). Therefore, according to Raymond et al. (2017) in the indicator introduced above, an increased health of the greenery is of a positive impact on the local society. I know of potential trade-offs and uncertainties, such as increased pollen production due to increased urban greenery, or the inconclusive or weak outcomes of some studies revolving around health and proximity to green areas. These relationships are extremely complex, and a simple analysis could miss some aspects, leaving out certain variables (Raymond et al., 2017). To avoid this, I suggest my own approach, which involved more than relying on the indicator itself. Instead, it entails gathering background insights from stakeholders, which could bring previously unknown aspects or variables to the light. This could mean, as in my case, engaging with a local organization like Ila Velforening or conducting an online survey targeting the residents. In a more comprehensive study this could for example include medical data.

4.5 Indicator III: Economical efficiency

Kabisch et al. (2016), in the group of indicators assessing transferability and monitoring, suggest assessing what is the percentage of the city budget allocated to urban greenery, implementation and maintenance. Raymond et al. (2017) in their framework, suggest certain forms of economic indicators, and as a main example of method they present a cost-benefit analysis. Cost-benefit analysis consists of comparing costs connected to the studied NbS to its benefits. It can also mean including alternatives to the nature-based solution and their costs and benefits (Raymond et al., 2017, p. v).

Such an approach to a NbS is possible as discussed in the theory chapter, through assessing it as the concept of an ecosystem services. I have decided to follow this approach and use cost-

benefit analysis to quantify ecosystem services and the economic efficiency of Iladalen Park as a NbS. The result of the cost-benefit analysis shows direct impact on the Trondheim Municipality economy as it is the municipality not the residents who bared the costs. Economically efficient and, successful NbS can play an important role in enhancing urban resilience and climate adaptation strategies as well as support policies (Biasin et al., 2023). It can also serve as an example and contribute to improving existing and future NbS. Economically inefficient NbS will can also aid in knowledge building and developing better solutions, but it could negatively affect citizens support or acceptance for of future NbS projects (Raymond et al., 2017b). Thus, indirect positive implications for residents could include efficient public spending on urban greenery, better climate adaptation and more successful NbS projects in future. For this purpose, I requested the costs of investment for the reopening of the Ila stream and the creation of Iladalen Park from Trondheim Municipal Engineering department (Kommunalteknikk, personal communication, April 8 & 12, 2024).

Unfortunately, maintenance costs are not included in the cost part of the analysis, because Trondheim municipality's City operation department (Bydrift) does not have detailed cost report for each park it takes care of. General costs for maintenance of inner-city parks in 2023 were about 24 million Norwegian kroner. This includes salaries, machinery, raw materials etc. Any maintenance cost since the creation of Iladalen Park should not be used for this analysis, as underlined by Municipality employee. In my email exchange with them they told me that these numbers are not necessarily specific or correct, and that they were not able to provide me with anything more detailed than that estimated costs for all the inner-city parks together (Bydrift Trondheim, personal communication, February 12, 2024). For this reason, I decided to use more precise investment cost for this analysis.

The quantified benefit of Iladalen Park is obtained through the academically recognized online software iTree. iTree is suggested as a tool for the assessment and calculation of ecosystem's services by Raymond et al. (2017). It is a peer-reviewed software created by the United States Department of Agriculture (USDA) Forest Service that allows for analysis and assessment of benefits of both rural and urban forestry. Most importantly for this analysis, it quantifies the environmental benefits provided by trees. An online version of the software *i-Tree Canopy* is used for the development of this indicator. The indicator estimates tree canopy and its benefits using a random point sampling over a satellite picture covering the studied area. The authors suggest a minimum of 500-100 survey points, as the accuracy of the

software increases with the amount of correctly identified survey points (i-Tree, n.d.). I drew the geographic boundaries of the studied area based on the google satellite picture of the park. The software then randomly generated the sample points within the park area.

Following iTree set up, I have classified 600 random survey points in the park area. The points were then classified accordingly to the following cover classes: Tree/Shrub, Brass/Herbaceous, Impervious Other, Water, Soil/Bare Ground. iTree initially suggests additional two classes- Impervious Building and Impervious road- however these were not important considering I only assessed specifically the park area- without the buildings or roads around it. Asphalt soccer field, walking paths and park's cottage were assigned to the Impervious Other Class.

The software estimates the value of the services based on specific numbers, these are available in the software report (see Appendix 4). The tool also includes a variable related to the climate, but unfortunately currently the closest climate setting station that can be used for the calculations is a climate in Sweden which will differ from the coastal city of Trondheim. Therefore, the iTree outcome will not be perfectly precise in representation of Trondheim (i-Tree, n.d.). This limitation of the instrument will be included in the analysis and discussion on the economic efficiency indicator.

iTree Canopy measures ecosystem services delivered by the trees in the study area. However, the main aspects of Iladalen Park are the storm water oriented NbS- detention pond and part of the renatured Ilabekken stream. I initially intended to calculate the ecosystem services delivered by these, using InVEST models, mentioned earlier in literature review. InVEST has been used for studies on NbS of similar nature (Biasin et al., 2023). The InVEST model calculating the service of urban flood risk mitigation and/or urban stormwater retention requires raster images and data (in tables form) regarding soil hydrological group, biophysical information, rainfall depth/ precipitation and information about built infrastructure (Natural Capital Project, 2024). As InVEST is an open-source software, and it has been created by the Standford University in the USA, the classifications that the software requires the input information to be in, varies from the classifications used in Norwegian data (Norsk institutt for bioøkonomi, 2019, pp. 16-50). I attempted on building up on another student's research, in which he connected the soil hydrological data with similar land use categories from the Norwegian Area Resource (AR) (Norsk institutt for bioøkonomi, n.d.;

Økland, 2022). I have obtained AR in the finest available resolution (AR5) and worked on preparing a raster image showing the soil hydrological groups according to the standard required by the InVEST software. AR5 classifies the area according to the criteria for area type, tree species, forest quality and soil conditions. Regrettably the data was not detailed enough for the Iladen park's scale and accurate classification translation. After limiting the AR layer to the Iladalen Park borders the only classes in the ground conditions were class 44 and 98. Class 44 named "Jorddekt" which could be directly translated to "soil-covered", and it is defined as an area with soil depth higher than 30 cm on more than 50% of the area. Class 98 translates directly into "not relevant" (Norsk institutt for bioøkonomi, 2019, n.d.). This does not provide enough criteria to translate it to the criteria required by InVEST. I then decided to check how did the soil in the park have been classified by the Norwegian Geological Survey, and it was assigned a "not classified" class (Norwegian Geological Survey, n.d.). At this point it was not possible for me to continue trying to collect the necessary information to input in the InVEST software, it was in fact impossible to get the data to the detail necessary for the model's calculations.

The ecosystem services delivered by the detention pond and the part of Ilabekken are too crucial for this indicator to be entirely omitted , therefore I decided to calculate a very rough estimate based on other studies which carried out detailed calculations of ecosystem services delivered by a bioretention area in an urban space. Zhan et al. (2020) conducted an assessment of the economic value of urban wetland ecosystem services in Zhuzhou City, China for which they used remote sensing imagery and multi-source data. The authors utilized economic valuation methods, adjusted economic data to 2016 prices, and considered various ecosystem services such as atmospheric composition regulation, climate regulation and water storage adjustment in their assessment. Through specific equations and methods for each service type, they estimated the total value of urban wetland ecosystem services and categorized them into ultimate and intermediate services to ensure accuracy and avoid double counting. The study evaluates the total value of urban wetland services in Zhuzhou to be over $ 1,5 billion annually. Different types of urban wetlands were assessed, and the findings were presented in a comprehensive manner, specifying ecosystem services for each type. In this study the authors classified the types of wetlands based on whether they are artificial or natural. Secondary type of classification, within the artificial type of wetlands, includes ponds smaller than 8 ha. Among types of ponds listed in the study, water storage pond and small landscape water bodies are listed. Evaluation methods used for calculating specific ecosystem

services delivered by ponds, among other types of the urban wetlands, include shadow project method, replacement cost method, market value method, travel cost method, result reference method and shadow price method. The final output is a table with the ultimate service values of different types of wetlands in Zhuzhou City. The types of services in Zhan et al. (2020) study, delivered by ponds included water storage regulation, climate regulation, tourism recreation, water supply, biological product, atmospheric composition regulation, preventing soil erosion and water purification. Among these services water storage regulation is the most similar to the services that I know of delivered by the detention pond in Iladalen (NVE, 2022). Assuming other services and calculating them would be too far off considering all the limitations of this approach that I explained above, most importantly the climate and environment differences between Zhuzhou and Trondheim. Reopening of Ilabekken had the goal of climate regulation and provided the space for tourism recreation however only a part of the stream runs through the park and Zhan et al. (2020) study does not cover stream ecosystem services as its focus is on urban wetlands. The value of water storage regulation in Zhuzhou detention ponds according to Zhan et al. (2020) is $ 21,7 ($ 10^3/ ha). I will present and discuss my calculations and results as well as limitations further in the results chapter.

This indicator adds yet another valuable point of view in assessing the social impact of the Iladalen park. Economical aspects are a part of many nature-based solutions assessment frameworks (Dumitru & Wendling, 2021; Kabisch et al., 2016; Raymond et al., 2017; World Bank, 2021). I recognize the limitations of the approach I ended up implementing and of the iTree software for the Norwegian setting. Yet a quantification of benefits of ecosystem services is helpful in delivering more tangible information for the assessment. It is also a measure that could be easily used in the future by other researchers interested in assessing the social impacts of NbS, especially when more climate settings become available in the iTree software.

4.6 Data Analysis

Out of the total ten questions in the survey, seven are closed answers yes/no or yes/I do not have an opinion/no. Three questions have follow-up sub questions, asking to indicate opinion on the scale, mark multiple answers or open answer. Two questions ask for opinion within a scale. Lastly, there is one open question, inquiring about participants' feelings while walking

through or using Iladalen park.

This survey, created in Nettsjkema, as already mentioned, has been distributed both in English and Norwegian, therefore the first step of my data analysis included the translation of the open questions. Next, answers to the scale and closed questions, expressing a positive opinion on Iladalen park or positive impact of the park, have been assigned a positive impact on the indicator and the assessment. No opinion or centre of the scale (participants indicated their opinion on a scale from 1 to 5, therefore centre of the scale is 3) have neutral impact on the indicator and the assessment. Finally, negative answers have a negative impact on the indicator and the assessment. I am basing this decision on Kabisch et al. (2016) and Buchel and Frantzeskaki (2015) works. Kabisch et al. (2016) suggested NbS impact on quality of life and wellbeing as an indicator, where positive impact on citizens quality of life, wellbeing or employment indicates good performance of the NbS. Thus, positive impact and respectively neutral and negative in case of neutral or negative impact on quality of life or wellbeing. I combined these aspects with citizen's perception as explained in Subchapter 4.3. Citizens positive perception of NbS can potentially lead to them supporting these and similar initiatives in the future, aid in conserving nature and creating better solutions in the future (Buchel & Frantzeskaki, 2015). Most importantly however their positive perception of NbS, urban greenery or ecosystem services can also be beneficial for the citizens themselves. Hadavi et al. (2018) argue that when citizens perceive urban greenery and NbS in a positive way it can contribute to their wellbeing as they are more likely to use these spaces, which then can contribute to their mental and physical wellbeing (Kolokotsa et al., 2020). For this reason, positive perception has a positive impact on the indicator and respectively neutral and negative.

The open questions and their impact on the indicator and assessment has been categorized and coded. Answers, similarly, to the previously described indicators, are divided into positive, neutral, and negative. Positive categories include words expressing happiness, wellbeing, appreciation of the park, recognition of its benefits, positive feelings, and relaxation. The neutral category includes short answers lacking a strong opinion. Negative category includes words expressing dissatisfaction, lack of wellbeing, criticism, minimizing park's role for the neighbourhood. Respectably, categorized answers have a positive, neutral, or negative impact on the indicator, and the assessment. As only a small part of the data required coding, it was done manually, with descriptive codes. Descriptive codes are the right

style for this data analysis as they represent opinions expressed, orally or written, in an obvious way by the participant (Cope, 2021). Open questions are very direct, and the survey was not supposed to take a lot of time, therefore I have received mainly straight forward answers.

Finally, it is important to explain the common scale on which the outcomes of the indicators have been weighted, and which suggested in the end whether the impact of the nature-based solution on the local society is negative, neutral, or positive. For the indicator using survey (Indicator I: Perception and Impact), each question has been assigned a weight depending on its importance- question asking more directly about the impact and perception have an outcome that ranges between –2 or 2. Lighter questions have been assigned –1,0 or 1. Finally, the weight of all the questions has been summed up. Negative value entails negative outcome of the indicator. Neutral outcome suggests no negative or positive impact. Outcome of 1 or higher suggests a general positive perception and impact. It is best to present indicators and the weight system in the Table 2.

Table 2. Common indicator metric.

Indicator	Questions relevant for creating the indicators		Weight of the answers		Final indicator weight	Assessment outcome
Impact and perception	No/ Yes	Scale 1-5	-2/2	-2/-1/0/1/2	-1/0/1	-1/0/1
		Multiple answer		-1/0/1 *		
	Scale 1-5		-2/-1/0/1/2			
	No/ No opinion/ Yes		-1/0/1			
	No/ Yes	Open question	-1/1	0/1		
	No/ Yes	No/ Yes	-1/1	-1/1		
	No/ No opinion/ Yes		-1/0/1			
	No / No opinion/ Yes		-1/0/1			
	Open question		-1/0/1			
	Scale 1-5		-2/-1/0/1/2			
	No/ No opinion/ Yes		-2/ 0/ 2			

Health and wellbeing	NDVI change Negative/ No change/ Positive	-1/0/1	-1/0/1	
Economic efficiency	Economic efficiency calculation result Negative/ Neutral/ Positive	-1/0/1	-1/0/1	

*Multiple answer and open questions in the first Indictor will be assigned -1/0/1 point after a qualitative analysis.

This scale is able to assess the indicators, obtained by fusing diverse types and amounts of data on one final scale, to get a clear answer to the assessment. Frameworks based on which this assessment has been created do not suggest a specific weight system, or a final value which suggests the successful rate of the studied NbS (Kabisch et al., 2016; Raymond et al., 2017). NbS cases, as explained in the introduction, vary extremely from case to case. There is no "one size fits all" way of assessing these solutions. This is an obvious limitation of this NbS assessment as well, but also of creating a framework in general. Geographical localization, climate, size, the issue for which the solution was engineered, social background- these and many other local and specific aspects shape how a given case should be assessed. With that said, this weight system coming down to a simple –1/0/1 scale, is an attempt to go around these limitations and estimate the general social impact of the Iladalen Park as a NbS, on the local society.

Other limitations that shaped this work are the Landsat satellite pictures. If such images are covered with clouds, they are useless in calculating the NDVI- thus limiting the number of pictures which can be used for the analysis. As presented in the results chapter (see Chapter 5), few summer composites didn't have enough cloudless pictures to identify median NDVI for the given year. iTree climate setting, was another limitation.
The discussed frameworks (Kabisch et al., 2016; Raymond et al., 2017; Raymond et al., 2017b) suggest many relevant indicators and aspects of NbS worth looking at however the scale of this master thesis does not allow for including more indicators. For this reason, I

aimed for very different sources and types of information to ensure data triangulation and including different relevant aspects of impact on a society.

In conclusion, the social impact of Iladalen Park as a nature-based solution on the local society of Ilsvika and Skansen area is assessed through the combination of the three presented and developed indicators. These indicators include perception and impact, health and wellbeing and economic efficiency. Different software and instruments have been used to collect, analyse and present the data. I have developed a common weight system in order to obtain a final answer suggesting whether the impact of Iladalen Park as a NbS on a local society is positive, negative or perhaps neutral. My contributions to the methodology include the creation of a common weight system and adjusting the framework to match local scale and context.

5 Results

5.1 Impact and perception

This chapter presents the key findings for each of the indicators. Beginning with the first indicator- online survey assessing citizens perception and impact of the park on their life (See Appendix 2 for survey results). Results from closed questions are presented in Table 3. Some of the questions allowed for multiple answers, and it was also possible to skip a question and continue to the following. For this reason, after calculating the answering percentage, I have included the number of participants who chose that given answer (see these values in parenthesis).

Table 3. Results from closed questions in the online survey.

Question	Answer	
Do you visit or use Iladalen Park?	Yes 98,2% (55)	No 1,8% (1)
If yes, indicate how often, on the scale from 1 (rarely) to 5 (daily)	1- 7,1% (4)	
	2- 19,6% (11)	
	3- 26,8% (15)	
	4- 30,4% (17)	
	5- 16,1% (9)	
If yes, how do you spend your time in Iladalen Park? (Multiple answers question)	Walking 75% (42)	
	Passing through 75% (42)	
	Exercising 8,9% (5)	
	Relaxing 58,9% (33)	
	Socializing 32,1% (18)	
	Other 16,1% (9)	
Indicate how much do you value green spaces in your neighbourhood on a scale from 1 (very little) to 5 (a lot).	1- 1,8% (1)	
	2- 0%	
	3- 0%	
	4- 5,4% (3)	
	5- 92,9% (52)	

Based on the urban greenery in your neighbourhood, are Municipality's initiatives on adding ore greenery desirable for you?	Yes 98,2% (55)	
	I do not have an opinion 0%	
	No 1,8% (1)	
Do you recognize any benefits that Iladalen Park provides for the neighbourhood as a community?	Yes 96,4% (53)	No 3,6% (2)
Do you know that Iladalen Park has additional climate adaptation functions?	Yes 25,5% (14)	No 74,5% (41)
If yes, do you think it is fulfilling its goal?	Yes 65,2% (15)	No 34,8% (8)
Does Iladalen Park improve the area's walkability?	Yes 92,9% (52)	
	I do not have an opinion 5,4% (3)	
	No 1,8% (1)	
Does Iladalen Park space improve the aesthetics of the area?	Yes 94,6% (53)	
	I do not have an opinion 3,6% (2)	
	No 1,8% (1)	
On the scale from 1 (strongly disagree) to 5 (strongly agree) would you agree with the statement: "The Iladalen Park improves the wellbeing of the neighbourhood"?	1- 0%	
	2- 1,8% (1)	
	3- 1,8% (1)	
	4- 14,3% (8)	
	5- 82,1% (46)	
Do you believe Iladalen Park positively impacts the quality of your life and your wellbeing?	Yes 96,4% (53)	
	I do not know 3,6% (2)	
	No 0%	

After calculating the points received by each answer following the metric scale (see Table 2), positive outcomes were overwhelming. All the answers presented in Table 3 were assigned a positive value.

Question "Do you recognize any benefits that Iladalen Park provides for the neighbourhood as a community?" in the Table 3, has been followed up by the open question «If yes, list them». Forty-four out of fifty-three participants answered this question with a yes. After a careful translation of the answers provided in Norwegian, the analysis of all the received answers, I have identified three main patterns.

One of the most recognized benefits by the participants is the space for social interactions. Many participants highlighted the importance of the park as a socializing area, as the place where they meet the neighbours, friends and strangers. Multiple participants emphasized the benefit of meeting others while walking the dogs, having a picnic or engaging in sport activities. One participant mentioned that the park is their main space for socializing and main source of interacting with the community. Multiple respondents highlighted the role of the park as the space where kids can play, but also as the space for elders to spend time outside.

Another benefit for the local community, recognized by the participants, is that the park can provide space for recreational and wellbeing activities. Numerous responses referred to the park as a space for relaxation and recreation. Participants appreciate the park as a green outdoor area that provides a place for mental rejuvenation close to the busy part of the city. In connection to the space for recreation and wellbeing, many respondents focused on the ecological aspect of the park and its role as a green lung of the neighbourhood, habitat for wildlife and an important part of urban environment. Several respondents considered the possibility to observe wildlife and natural features (stream and detention pond in the park) as a benefit for the local community, recognizing the importance of a green space within the city. In total, 78% of all the participants recognized at least one benefit of the park for the community. Some answers listed as many as six benefits. For this reason, this question receives 1 point in the common scale (see Table 2). It would be possible to rate it 0 if there were very few answers and examples of the benefits, since just answering the question suggests positive connotations.

Lastly, the survey included one open question «How do you feel when visiting the park or using it for recreation?», which has been answered by forty-nine participants. Once again, after careful translation and analysis of the answers, I have identified few patterns. For the analysis of these answers I used descriptive coding, as mentioned in Chapter 4. I have manually assigned the answers to categories. Positive category includes words expressing happiness, wellbeing, appreciation of the park, recognition of its benefits, positive feelings, and relaxation. The neutral category includes short, neutral answers lacking a strong opinion. Negative category includes words expressing dissatisfaction, lack of wellbeing, criticism, minimizing park's role for the neighbourhood. Forty-eight answers included wording of the

first category and only one answer expressed neutral sentiments, literally by answering the question “How do you feel when visiting the park or using it for recreation?” with “Neutral”. For this reason, in the common scale metric this open question received 1 point on the scale from -1 to 1.

Among the positive answers, I have identified three main trends. The most common sentiment expressed by participants is relaxation, with many answers including only single word such as “Relaxed”, “Calm”, or “Content”. Other single word used as answers included “Happy” and “Good”. Connection with nature was an important aspect of the relaxation for many respondents. Some respondents who answered that they feel relaxed, happy, content or calm connected these feelings to being surrounded by nature. Here some examples of such answers: “Gives peace and joy. Brings nature closer. A little colour in the neighbourhood”, “It provides peace and reduces stress, gives an immediate proximity to nature”. Few answers specifically focused on biodiversity and on the sounds of the stream going through the park: “I feel relaxed and the trickle from the open stream gives me peace. We are right next to Iladalen and have the green areas as our neighbour. Very lucky!”, or
“Calm, with the stream rushing through and giving life to other animals”.

To summarize, the participants painted a very positive image of the park through the survey, with very few negative or neutral answers. Both closed and open questions suggest that Iladalen Park has a positive impact on the citizens living in the area, and it seems to have a positive impact on their lives. I conclude the latter based on the 96,4% positive answers to the question “Do you believe Iladalen Park positively impacts the quality of your life and your wellbeing?” as well as on the participants emphasis on the park’s role in facilitating socialization. This will be discussed further in the next chapter, however the result of this indicator in my metric scale suggests a positive impact.

5.2 Health and wellbeing

The NDVI calculation in Google Earth Engine Code Editor provided following results. Within the area of the Iladalen Park the value of NDVI in the years before parks creation varied between 0,08 and 0,78 whereas the NDVI value after parks creation varies between 0,42 and 0,84 over the years. NDVI values for specific summer periods are presented in the

Table 4. The “null” value means that given summer composite did not have enough cloudless pictures to determine the NDVI (explained as a limitation in Chapter 4). If NDVI analysis was done on a global scale, very low values oscillating around 0,1 represent barren areas. Moderate values around 0,3 suggest shrubs and grass while high values, from 0,6 up suggest healthy vegetation on a global scale comparable to tropical and temperate rainforests (Weier & Herring, 2000). Therefore, although the NDVI maximum values before parks creation did go up to 0,78, the minimum values were noticeably lower than the minimum values after the park’s creation. Maximum values have also improved after the park’s creation- ranging from 0,79 to 0,84 in the assessed years, suggesting very healthy vegetation.

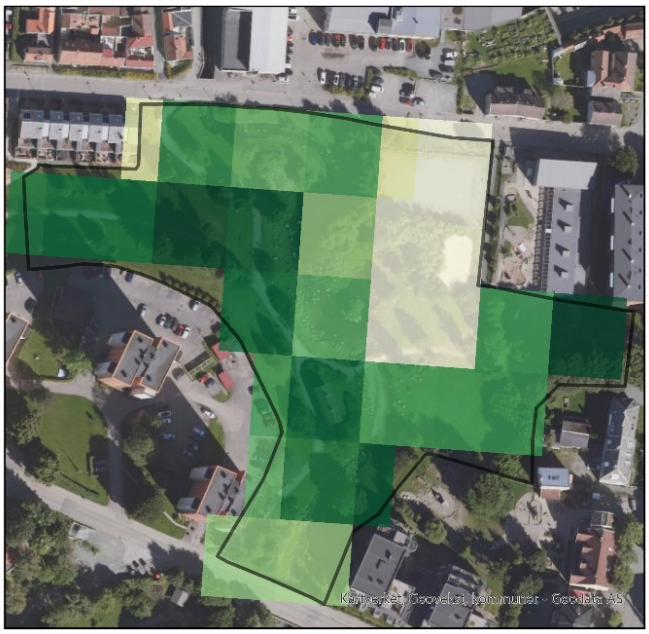
Table 4. NDVI results over summer periods.

Year	NDVI	Year	NDVI
1999	null	2018	null
2000	null	2019	null
2001	0,12- 0,69	2020	0,44- 0,79
2002	null	2021	0,48- 0,83
2003	0,08- 0,78	2022	0,50- 0,84
2004	0,10- 0,72	2023	0,42- 0,84

As visible on Map 2 and Map 3, which present the NDVI results from 2004 versus 2023, the NDVI value clearly grew along the reopened stream and retention pond. Therefore, not only did the NDVI value improve but the number of areas with high NDVI increased. According to the common metric scale (see Table 2) the increase of NDVI value after the creation of the park is considered as a positive impact on the local society, thus giving the indicator a 1 on the -1 to 1 scale. The implications of these results will be discussed further in the next chapter.

Map 2. NDVI value in Iladalen Park in 2004

1:1,800



Map 3. NDVI value in Iladalen Park in 2023

1:1,800

Legend

Iladalen Park Boundaries

NDVI 2004

Value

0.72

0.10

NDVI 2023

Value

0.84

0.42

0.1

Kilometers

Lower Right: 10°22'E 63°25'47"N

N

Spatial Reference
Name: ETRS 1989 UTM Zone 33N
Projection: Transverse Mercator

Credits: Own work, Kartverket, Geovekst, kommuner - Geodata AS

5.3 Economic efficiency

Based on the project settings (climate, currency and metric system) and 600 survey points I classified in the iTree Canopy software, within the area of Iladalen Park, the software generated report with the results of analysis. For the report see Appendix 4. They go as follows. The land cover of the park consists of Grass/ Herbaceous 41,75% (Standard Error (SE) ± 2,01%), Water 9,18% (SE ± 1,18%), Tree/Shrub 34,22% (SE ± 1,94%), Soil/ Bare Ground 2,34% (SE ± 0,62%), and Other Impervious areas 12,69% (SE ± 1,36%). The ecosystem services of the area are estimated in three categories: Carbon, Air Pollution and Hydrological.

According to the report the trees in Iladalen Park Sequester 1,91 tones (SE ± 0,11) of carbon annually or 7,02 tones (SE ± 0,40) of CO_2 annually, providing services worth of 3 172 NOK (SE ± 180).

Next in terms of air pollution, the park, annually removes: 1kg of Carbon minoxide, 23,97 kg of Nitrogen Dioxide, 112,23 kg of Ozone, 9,85 kg of Sulfur Dioxide, 9,20 kg of Particulate Matter smaller than 2,5 microns and 32,33 kg of Particulate Matter greater than 2,5 microns. Overall, the park removes 188,58 kg (SE ± 10,68) of air pollution, delivering a service worth 8154 NOK (SE ± 462) a year.

Lastly the hydrological estimated benefit of the Iladalen Park refers to the avoided runoff- amount of water that trees help prevent from running off the surface and potentially causing erosion or flooding. It is estimated that for every square meter of land covered by trees, approximately 5.20 kilolitres (SE ± 0,29) of water per year are prevented from runoff. This service amounts to 103 NOK per year. There are other hydrological benefits, however the software didn't have enough data to generate the estimated cost of these services.

To summarize presented above services, together, from 2010 till 2023 were estimated to be worth roughly 160 006 NOK. I only calculate these benefits from 2010 on since as previously mentioned the road construction went on until 2009. Additionally, as visible on spatial images the Park only became really green from 2010 on. I also want to emphasize the words estimate and roughly in the iTree analysis since the vegetation changes and grows from year

to year. It is important to mention at this point that iTree software doesn't calculate the worth of services delivered by the NbS itself. Calculating Ecosystem Services of NbS and specifically detention ponds and other solutions aiding in managing 100-year floods and other negative impacts of increase precipitation could be a separate research with the InVEST software.

However as discussed in previous chapter (see Chapter 4) I was not able to obtain detailed relevant data for the scale and location of my study, thus I decided to utilize Zhan et al. (2020) research for my rough estimate of the ecosystem services delivered by the detention pond in Iladalen Park. I decided to use Zhan et al. (2020) study, for their detailed analysis and value estimates varying between different types within the urban wetland system- including artificial ponds. I used their estimated value of water storage regulation in a calculation with the size of Iladalen pond, which is 0,0495ha.

$21,7 \times 10^3 \times 0,0495 = 1074,15$ $/ annually

Thus a rough estimated value of water storage regulation delivered by the detention pond in Iladalen Park is of 1074,15$ per year which with the exchange rate from the April 22nd, 2024, is 11848.58 NOK annually. This value amounts to 189 577,28 NOK worth of ecosystem services delivered between 2008 (when the park was opened) and 2023. However, I want to underline the differences, limitations and issues of my approach. Zhuzhou is located in a subtropical monsoon climate zone, thus an entirely different climate than Trondheim, and as emphasized by Zhan et al. (2020) value of ecosystem services vary in space and time. With different ecosystem- ecosystem services are being delivered differently. I attempted to focus only on the artificial ponds and adjusted their calculation to the Iladalen detention pond size however still the same study carried out in Trondheim climate could bring out different result. I brought in this estimate knowing that it will not change the result of economic efficiency indicator. I believed that omitting mentioning water services entirely would be inaccurate hence my attempt on more accurate representation of ecosystem services delivered by Iladalen park with full recognition that the numbers used for calculation could vary in Trondheim. I want to emphasize that this estimated value of 1074,15$ per year, should not be used further in any studies. I want to suggest using InVEST software.

In terms of costs Trondheim Municipality's department of Municipal Engineering in email

exchange provided me with the final costs of the project rounded up in millions of Norwegian Kroners. Obtaining this data in more detailed format proved difficult since the project was already under development nearly 20 years ago. Due to many aspects of the project being connected with the underground relief road I will focus only on the Iladalen Park and Ilabekken reopening. It is important to remember however that Ilabekken runs through the park but also for few hundred meters before and after the park. Therefore, area of construction cost is larger than the area of Iladalen Park. According to the document presenting final rounded up costs and how they were divided between different actors, reopening of Ilabekken costed 10 million NOK, this included reopening of 700 meters of Ilabekken until the exit to the Fjord, preparation of the open space for Iladalen Park, walking path, volleyball field and a playground. The actual creation of Iladalen Park (Landscape, vegetation, paths etc) costed 6 million Kroner. Together the cost shared between actors for these two aspects comes up to 16 million NOK (Kommunalteknikk, personal communication, April 8, 2024).

Thus without calculations the costs of the project (16 million) far exceed the worth of calculated ecosystem services provided by the vegetation and pond in Iladalen Park which amounted to estimated 349 583 NOK since the parks creation.

6 Discussion

6.1 Interpretation of results

The objective of my research was to assess the social impact of Iladalen Park as a NbS. Through three different indicators I aimed to assess different aspects of impact on local society, and determine whether the impact is negative, neutral or positive as well as discuss the implications following. In this chapter I provide and discuss final answer to the research question:
How is Iladalen Park as a Nature-based Solution performing in terms of social impact, and what implications does it have for the local community?

As described in the results chapter (see Chapter 5), the results of indicators are as follows:
1) Impact and perception- positive,
2) Health and wellbeing- positive,
3) Economic efficiency- negative.
According to the metric scale provided in Table 2 this suggests a positive impact of the Iladalen Park as an NbS on the local society. Impacts on the local society for these indicators include creation of well received park and space for socialisation and relaxation which, according to residents, improves their quality of life. They include improved health of the greenery and biodiversity in the park as well as delivery of tangible ecosystem services and climate adaptation over the years. Now what are the direct and indirect implications of these impacts for the local community?

They resulted or can result in facilitating easy contact with nature, increased usage of the park (Hadavi et al., 2018), more social gatherings and socialisation in the neighbourhood, facilitating recreation (Ila Velforening, personal communication, April 24, 2024) as well as increasing wellbeing (Kolokotsa et al., 2020). Indirectly they could result in more support or participation in future NbS or urban greening projects leading to more successful projects in the city or in the neighbourhood. Negative result of economic efficiency indicator could lead

to less support or stakeholders' acceptance in the future, which could pose challenge in future greening initiatives (Raymond et al., 2017b). I will now discuss these in detail.

The overwhelming majority of the online survey participants expressed opinion suggesting being very fond of the park and believed that the park improves their quality of life and supports wellbeing. Additionally, the park, as a green-blue corridor, now provides continuity between the forest and the park, making the park a starting point for hiking up along the stream. Local population has therefore even easier access to nature and appreciates it. Many participants were specifically fond of the sounds of reopened stream and the wildlife that the nature-like form of the park invites. Ila Velforening, the neighbourhood's community development organization, noticed that another highly appreciated aspect by the stakeholders, is that they can now begin their hike in the neighbourhood without walking along busy streets- they start their walk in the park, and they are straight away interacting with nature. As mentioned previously neighbourhood's attractiveness and reputation improved from the 1990's (Ila Velforening, personal communication, April 24, 2024).

Revisiting the problem statement, citizens acceptance and support for NbS projects is crucial for their success and for support and participation in future greening or NbS projects (Giordano et al., 2020; Raymond et al., 2017b). In return citizens positive perception on an urban green space can positively influence their usage and enhance residents' wellbeing through contact with greenery (Hadavi et al., 2018; Kolokotsa et al., 2020). Their support can also aid in creating more such projects in the future (Raymond et al., 2017b). Inhabitants of the studied area (with postal code 7018) made their support for the local park, or even pride in living next to park very clear. The park can thus be called a success on all fronts, not only did it receive national prise, but it is embraced and held in high regard by the citizens and most importantly by the stakeholders. This could aid future greening projects in the neighbourhood. According to Ila Velforening, ethnic minorities and people of immigrant background are especially good in utilizing the park for social gatherings and community events such as picnics. One survey participant with immigrant background even implied that the park is their main source of socialization and that they really appreciate it for this reason. Thus, one of the implications of the park is that it provides an inclusive and open space for all citizens and facilities socialisation (Ila Velforening, personal communication, April 24, 2024).

Moving on to the NDVI value increase, while that's clear sign of the NbS performing well, as increasing biodiversity and improving connectivity was an objective of the project, it is even more positive in the context of urbanisation. Trondheim Municipality underlines the need for urban densification with the aim of avoiding urban sprawl (Kommunalteknikk, personal communication, April 8, 2024). The city is thus densifying and, based on the satellite images of Trondheim spanning several years, available online, Ila as a neighbourhood has been densifying already prior to the Ilabekken and relief road project (Statens Kartverk, n.d.). Therefore, the park improved greenery health, and it did so for a growing population of Ila, preserving a natural green space very close to the dense, busy city centre. Alternatively, the area could be also built up, or covered with more regular green open space. Therefore, such detailed project which included two NbS, accomplished multiple goals and co-benefits with single action- increasing the NDVI, providing climate adaptation and ensuring small nature enclave in a form of a blue-green corridor close to Trondheim's centre. It created a healthy green space even closer to the citizens.

Ila Velforening noticed a big increase in outdoor activity in the neighbourhood since the creation of the park. People of all age take part in hiking groups, picnics and recreation activities in the park area (Ila Velforening, personal communication, April 24, 2024). I believe this aspect – increased recreation in the park with healthier greenery, is connected to the studies discussed in this thesis which suggest interacting with nature increases physical and mental wellbeing (Haybron, 2011; Kolokotsa et al., 2020; Lee & Maheswaran, 2011; Tzoulas et al., 2007; Ulrich, 1984; Van den Bosch & Sang, 2017). My interpretation of increased NDVI value, stakeholders' fondness of the park and background information from Ila Velforening, is that the Park really helped in improving the neighbourhood, facilitating contact with nature, recreation and creating a space for community. Therefore, having a positive impact on local society and the implication being increased quality of life. One downside of this situation could be that since Ila is now an attractive area, a green gentrification could take place, however this requires further research (Bockarjova et al., 2020).

Moving on to the results of the economic efficiency indicator, I realised that while it is still an immensely relevant indicator, the case of Iladalen is somewhat challenging to do it justice. The steep price of the project was connected with the very demanding project of moving the European road E6 underground close to the shoreline. If it was not for the E6, the NbS

creation would take much less time and it would not require as many resources. According to the information provided by Municipal Engineering department- the cost of the green area of the park itself was 6 million kroner (Kommunalteknikk, personal communication, April 8, 2024). Additionally, the project and its high cost provided more than environmental services on which I focused in the context of Iladalen Park. The relief road provides services to the inhabitants of the city which are not calculated here, such as improved communication or decreased traffic. Moving it underground- therefore ensuring little changes to the historical neighbourhood above the ground, is also a service which is not calculated or discussed in this thesis.

Therefore, in the hindsight I realise that a complete full cost-benefit analysis of the project including relief road, Iladalen Park, reopening of Ilabekken, providing space for recreation, improved biodiversity and other additional features of the project, could be a separate research. I still believe that my approach was a good attempt, but perhaps not for projects of such complexity and of such transformative power. If I only considered the 6 million kroner spent on the creation of the park, it would take 257 years for the ecosystem services of trees and pond to return the investment. My assumption is that, since "only" some of all the provided services amounted to one-third of a million over the years, if all possible ecosystem services and value of the whole stream and the park together were calculated (such as the recreational value, regulating flood risk, carbon sequestration of the water features) they would only have a couple of years left of "paying back" for the cost of investment. Such full analysis could also include the cost of keeping the piped stream as it is and should consider costs of potential infrastructure damage without the climate adaptation functions of the reopened floodway and detention pond. This, however, is only my assumption looking back on how many things should be considered and could be calculated with more data available.

With the results that I did obtain however the negative impact is mainly for Trondheim Municipality as the cost bearer. The residents still benefited from the climate adaptation and other ecosystem services delivered by the park over the years. Indirect negative implication for the residents could be decreased stakeholder support or acceptance of greening or NbS projects in the future. Which could pose a challenge in future greening initiatives (Raymond et al., 2017b).

Although the result of economic efficiency indicator was negative, I believe that Iladalen

Park can overall be referred to as a success anyways. Its creation had a positive impact and positive implications for the residents in terms of the social impact and greenery health improvement. Iladalen therefore fulfils its role, benefiting environment and adapting to climate thus serving a specific goal and benefiting local society. There is one problem however, linked to the questions in the online survey that inquired whether the participants are aware of the park's climate adaptation features. Only the 25,5% answered positively. Which means that the majority of the stakeholders view Iladalen as "just" a park. Therefore, although there is a lot of support towards the project from the stakeholders, they are not aware of the full extent of it, they do not know that the park and its features have been designed to handle increasing precipitations and intensified weather events expected with climate change. In other words, stakeholders support the project without being fully aware that they are supporting it as well as NbS. As Giordano et al. (2020); Kabisch et al. (2016) and Raymond et al. (2017b) argue- citizens support is crucial for NbS success. I hope my research could support the Municipality and other actors with data creating the opportunity to present Ildalen as a successful NbS case, a chance to advocate for NbS in Norwegian urban space.

Kommunalteknik provided me with municipality's application for the urban environmental prise that was later won by the project in 2010. The application discusses a very relevant aspect connected to advocating for NbS. In a way this project has been "easy" as majority of the land that went under construction, belonged to the municipality. Therefore, there were not many private actors to consider and to get on board with (Kommunalteknikk, personal communication, April 8, 2024). Which gave a lot of opportunities.
Chance is that otherwise, trying to create a NbS in the city will affect more private actors and stakeholders. Other projects might require more cooperation between the Municipality and the different stakeholders, limiting the opportunities. Having such successful case of NbS as an example- showing how it can improve the area, provide many benefits, how other citizens enjoy the NbS in their area could help in facilitating cooperation or at least future stakeholders' acceptance. Which for the last time, has been argued to be crucial for NbS success and can be beneficial for the residents themselves.

6.2 Comparison with existing literature

In the literature review chapter (see Chapter 2), I discussed a cost-benefit analysis of different NbS scenarios in Turin, Italy by Biasin et al. (2023). The objective was to analyse and compare different NbS cases in Turin and determine which climate adaptation services exceed the costs of investment. For their analysis Biasin et al. (2023) used InVEST models, which utilize GIS data such as average precipitation raster images over the area of interest (Natural Capital Project, 2024). Both Biasin et al. (2023) and my research revisit existing NbS case studies and analyse their impact through multiple indicators using GIS related software, they do it from different points of view. Looking back, I think research with an objective like mine could be done through a survey and InVEST models with more time and available detailed data. Biasin et al. (2023) cover the economic aspect so well that their tangible results can support policy and decision makers in Turin. Such analysis could be useful in any city aiming for climate adaptation through NbS. However, the InVEST models are time consuming and require a lot of very detailed GIS data. Although less tangible, I believe my results can support decision makers too, as I mentioned before, through delivering data to inform future projects and gain acceptance. Biasin et al. (2023) while mentioning potential positive social impact, do not deliver actual citizen's opinions and their testimonies on social benefits which is a relevant tool for urban decision makers.

Another relevant aspect in connection with Biasin et al. (2023) is that in their analysis they suggested implementing NbS which costs exceed benefits in a targeted manner (see Subchapter 2.4). Costs were bound to be big considering the scale of the construction and the multiple objectives of the Ilabekken and Iladalen project. I think Iladalen with NbS within it is such a case, where targeted costly implementation is justified to meet multiple goals and objectives.

In the previous chapters I have also discussed in detail the concept of wellbeing and wellbeing studies. I brought up few of many studies assessing wellbeing in the space context. My survey results, on a small scale, contribute to these arguments and proofs of nature's positive impact on mental and physical wellbeing. Participants in my study, through both closed and opened questions, made clear that they consider the park having a positive impact on the neighbourhood and on their lives. When I shared the survey, I did not expect so many

participants and such positive feedback on the park and local greenery. My personal observation is that in Trondheim, nature is generally accessible. Especially in Ila, the hiking paths start just few hundred meters from most households. It could be thus expected that the park would not be of such importance for the inhabitants of the neighbourhood.
However it seems that although the mountains and nature are all around Trondheim the participants still highly value the possibility of immediate interaction with nature and enjoy the park the same.

Another aspect here is the community life- although it requires further research- it seems that the greenery positively influenced social life and community space in the neighbourhood. One part of it is participants often mentioning throughout the survey that the park gives them the opportunity to talk to their neighbours and strangers, to fellow dog owners, to bring their kids for play etc. However, the follow-up conversation with Ila Velforening brings the context of time- according to the organization the number of social events, gatherings or just picknicks has increased by a lot since the park's creation. In the previous chapters I also discussed the case of green and grey parts of Manhattan, and how this setting influenced the sense of community and the amount of socialisation. Haybron (2011) discussed how the inhabitants of the "green" neighbourhoods were more likely to know their neighbours and have more social ties within the neighbourhood. Which then again- can have a positive impact on one's wellbeing (Haybron, 2011). I think with further research the case of Ila would additionally support Haybron's (2011) research.

Lastly, I want to discuss the Eklipse framework (Raymond et al., 2017), as it has been created for the purpose of studies like mine. In the initial phases of my research, I expected to find more detailed step-by step approaches to assessing NbS from the social studies angle. I thought of Eklipse as a very general, source with examples of case studies, methods and software. However, at this stage I think Eklipse and NbS documents of similar format are the only right way to conceptualise NbS assessment. Although the list of types of NbS is finite, the context in which they are being created is not. Just through the course of my research I had to adjust my indicators and my approach accordingly with new information and data influencing the context of the study. Therefore, although it could be possible to create an assessment framework for each type of NbS- it still would not work for all cases out there. For this reason, I believe that Eklipse and other works of that type- have the right format to

work with- they allow for picking out the right indicator and the right methodology or software according to the NbS case but also to researchers' time and resources available.

7 Conclusion

Through my research question: How is Iladalen Park as a NbS performing in terms of social impact, and what implications does it have for the local community? I attempted to contribute to knowledge building in the NbS field and to address the local needs. Assessing NbS after their implementation, even if the given case was failing, was argued to be crucial for NbS development and more successful projects in the future. I believe that revisiting this very successful case provides nuanced localized knowledge.

My objective was to determine whether the impact was negative, neutral or positive. I obtained tangible data on citizens perception and opinion on Iladalen Park, on greenery health improvement and on the ecosystem services delivered by Iladalen Park and utilized it to develop three indicators able to determine the character of the impact. Through data analysis and additional background information obtained from local actors, I determined that Iladalen's impact on the local society is positive. I believe my research provides tools for the Trondheim Municipality to communicate with the residents about NbS which could be helpful in case of future NbS projects in the city. This was very relevant for the municipality according to Universitetenskommune employee.

I achieved the goal of my study which was to assess the social impact of Iladalen Park, determine and discuss the character of this impact. My objective was to provide nuanced knowledge on local NbS. One aspect of my research in which I fell short was the ecosystem services calculation. Data and time limitation, but mostly underestimation of the complexity of these calculations stopped me from delivering a strong economic efficiency indicator.

I encountered several limitations during data collection, the first of them being limited climate setting in the iTree Canopy online software. The software closest available climate setting for the ecosystem services estimate was the climate of Sweden which could have had an influence on the calculated Trees benefits. Another limitation revolved around NDVI analysis. Older green interventions could be challenging for few sources of high-quality satellite pictures, which are limited even further with potential cloud coverage. Therefore, for

a comparative analysis such as this one, other geo-indicators should be considered. Raymond et al. (2017) provides a diverse and comprehensive list of geo-indicators that could be considered in such situation.

Assessing ecosystem services requires much more time than anticipated due to the complexity of the factors influencing the services. At the time of analyses, I tried multiple software (iTree and InVEST among them) allowing for evaluation of this services, and the more comprehensive ones such as InVEST provides detailed analysis but require considerate data input. Therefore, my biggest limitation was the time limit of my research and the accessibility to detailed GIS data.

Another limitation which was unforeseen and influenced my workflow was Trondheim' Municipality unclear data and information organization. From the early stages of my research, it was hard to receive any information from the Municipality. That is not to say that the employees are not responsive- I have been redirected between departments and different employees' multiple times. I want to note that the biggest obstacle in this sense was not being able to get any information from Trondheim municipality on list of NbS in the Municipality. I was forced to settle for the one case I did know about myself- Iladalen Park.

After my research I see the need for more NbS case studies and assessments. There are many frameworks, indicators and guides available. Green gentrification is a relevant topic to assess with connection to NbS implementation as well (at Ila and elsewhere). Lastly the NbS field could benefit from more economical assessments and further development of tools aiding in calculating ecosystem services. I also see remote sensing and GIS based software's as a great way to assess NbS cases without much or any resources.
I believe Google Earth Engine, InVEST, iTree and ArcGIS are extremely useful tools in assessing the impacts of NbS and I would recommend them to anyone interested in the topic.

I hope my research can contribute to the growing development of NbS assessment field and bring attention to smart urban solutions for climate adaptation. NbS like Iladalen Park case can be a great alternative to the traditional grey infrastructure. The case proves that NbS can benefit both the nature and the residents, they can serve as a useful tool in climate adaptation strategies while making the city a more attractive place fostering wellbeing. The multifunctionality and the co-benefits of NbS are available for all cities, but for their success

more assessments and performance studies are needed on the already existing NbS.

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9 Appendices

9.1 Appendix 1. Survey letter and questions in English and Norwegian

Dear participant,

My name is Joanna Radkiewicz, and I am a master Student at the Department of Geography at NTNU-Trondheim. I am developing my master thesis, that focuses on assessing the social impact of Iladalen park, a nature-based solution in your neighbourhood. The goal of my research is to determine if and how Iladalen park impacts the local residents. Through my research I hope to support and help the administration in the efforts to improve and develop the urban greenery in Trondheim.
This survey is a crucial part of my research. The aim is to study and assess your perception of the green spaces in your neighbourhood, as well as whether these areas have any impact on the quality of your life. **It is important that as a participant you are above 18 years old and live within the 7018-post code area in Trondheim (Ilsvika and Skansen area).**
It takes approximately 5 minutes to fill it out, and it is completely voluntary and confidential. I will not have access to your email address after you submit the survey, it is anonymous. Submission of filled out survey will be considered as your consent to participate in the survey.
I would appreciate it if you could fill it out at your earliest convenience and no later than March 15th. At any point in the research, you have the right to withdraw your answers.
By June 1st, 2024, all the data collected through these surveys will be deleted. Until then it will be stored on a password protected cloud.

Note that there are no right or wrong answers, and your opinions are of great value in building a better understanding around more successful urban nature solutions.

Thank you in advance for your participation, and your help in developing my Master thesis.

Joanna Radkiewicz
Student in Globalization and Sustainable Development
Department of Geography – NTNU, Trondheim

If you have any questions, complaints, or concerns regarding how the research is conducted, feel free to contact me directly, or my supervisors responsible for my research,
Martina Calovi and Hilde Nymoen Rørtveit, at the following email addresses:

Joanna joannalr@stud.ntnu.no

Martina martina.calovi@ntnu.no
Hilde hilde.nymoen.rortveit@ntnu.no

Kjære deltaker,
Jeg heter Joanna Radkiewicz, og er masterstudent ved Institutt for geografi ved NTNU-Trondheim. Jeg skriver for øyeblikket en masteroppgave som skal vurdere den sosiale betydningen av Iladalen park, en naturbasert løsning i ditt nabolag. Målet med oppgaven min er å finne ut om og hvordan Iladalen park påvirker lokalbefolkningen. Denne forskningen forsøker å bidra til å støtte Trondheim kommune i arbeidet med å forbedre og utvikle de urbane grøntområdene i Trondheim. Denne spørreundersøkelsen er en viktig del av forskningsprosjektet. Målet er å studere og vurdere din oppfatning av grøntområdene i nabolaget ditt, samt om disse områdene har noen innvirkning på livskvaliteten din. Det er viktig at du som deltaker er over 18 år og bor innenfor postnummerområdet 7018 i Trondheim (Ilsvika- og Skansenområdet). Det tar omtrent 5 minutter å fylle det ut, og det er helt frivillig og konfidensielt. Jeg vil ikke ha tilgang til e-postadressen din etter at du har sendt inn undersøkelsen, den er anonym. Innsending av utfylt undersøkelse vil bli betraktet som ditt samtykke til å delta i undersøkelsen. Jeg ville satt pris på om du kan fylle ut undersøkelsen så tidlig som mulig og senest 21. mars. Når som helst i undersøkelsen har du rett til å trekke svarene dine. Innen 1. juni 2024 vil alle data som er samlet inn gjennom disse undersøkelsene, bli slettet. Inntil da vil den bli lagret på en passordbeskyttet sky. Merk at det ikke finnes riktige eller gale svar, og dine meninger er av stor verdi for å bygge en bedre forståelse rundt mer vellykkede bynaturløsninger.
På forhånd takk for din deltakelse, og din hjelp til å utvikle masteroppgaven min.
Joanna Radkiewicz
Student i globalisering og bærekraftig utvikling Institutt for geografi – NTNU, Trondheim

Hvis du har spørsmål, klager eller bekymringer angående hvordan forskningen utføres, kan du gjerne kontakte meg direkte, eller veilederne mine som er ansvarlige for forskningen min, Martina Calovi og Hilde Nymoen Rørtveit, på følgende e-postadresser:
Joanna joannalr@stud.ntnu.no

Martina martina.calovi@ntnu.no
Hilde hilde.nymoen.rortveit@ntnu.no

Besøker eller bruker du Iladalen parken?
Do you visit or use Iladalen park?
Yes/ No

Hvis ja, angi hvor ofte, på skalaen fra 1 (sjelden) til 5 (daglig).
If yes, indicate how often, on the scale from 1 (rarely) to 5 (daily).

Hvis ja, hvordan tilbringer du tiden din iIladalen parken?
If yes, how do you spend your time in Iladalen park?

Rusle (walking)
Går igjennom (passing through)
Trener (exercising)
Slapper av (relaxing)
Sosialisere (socializing)
Annet (other)

Angi hvor mye du verdsetter grønne områder i nabolaget ditt på skalaen fra 1 (svært lite) til 5 (mye).
Indicate how much do you value green spaces in your neighborhood on a scale from 1 (very little) to 5 (a lot).

Basert på det urbane grøntområdet i nabolaget ditt, er kommunes initiativ for å tilføre mer grønt ønskelig for deg?
Based on the urban greenery in your neighborhood, are Kommune's initiatives on adding more greenery desirable for you?
Yes/ I do not have an opinion/ No

Annerkjenner du noen av fordelene som Iladalen park gir til nabolaget som fellesskap?
Do you recognize any benefits that Iladalen park provides for the neighborhood as a community?
Yes/ No

Hvis ja, vennligst oppgi dem.
If yes please list them.
Open question

Vet du at Iladalen park har flere klimatilpasningsfunksjoner?
Do you know that Iladalen park has additional, climate adaptation functions?
Yes/ No

Hvis ja, tror du det oppfyller målet?
If yes, do you think it's fulfilling its goal?
Yes/ No

Forbedrer Iladalen park områdets gangbarhet?
Does Iladalen park improve the area's walkability?
Yes/ I do not have an opinion/ No

Forbedrer Iladalen park områdets estetikk?
Does Iladalen park space improve the aesthetics of the area?
Yes/ I do not have an opinion/ No

Hvordan føler du deg når du besøker parken, eller bruker den til rekreasjon?
How do you feel when visiting the park, or using it for recreation?
Open question

På skalaen fra 1 (helt uenig) til 5 (helt enig), hvor enig er du i påstanden: "Den Iladalen parken forbedrer velværen i nabolaget"?
On the scale from 1 (strongly disagree) to 5 (strongly agree) would you agree with the statement: "The Iladalen park improves the wellbeing of the neighborhood"?

Tror du at Iladalen park påvirker din livskvalitet og velvære positivt?
Do you believe Iladalen park positively impacts the quality of your life and your wellbeing?
Yes/ I do not know/ No

9.2 Appendix 2. Survey results- report from Nettskjema

Nettskjema

Social Impact of Iladalen Park

Updated: 14 May 2024 at 11:51

Kjære deltaker,

Jeg heter Joanna Radkiewicz, og er masterstudent ved Institutt for geografi ved NTNU-Trondheim. Jeg skriver for øyeblikket en masteroppgave som skal vurdere den sosiale betydningen av Iladalen park, en naturbasert løsning i ditt nabolag. Målet med oppgaven min er å finne ut om og hvordan Iladalen park påvirker lokalbefolkningen. Denne forskningen forsøker å bidra til å støtte Trondheim kommune i arbeidet med å forbedre og utvikle de urbane grøntområdene i Trondheim.
Denne spørreundersøkelsen er en viktig del av forskningsprosjektet. Målet er å studere og vurdere din oppfatning av grøntområdene i nabolaget ditt, samt om disse områdene har noen innvirkning på livskvaliteten din. **Det er viktig at du som deltaker er over 18 år og bor innenfor postnummerområdet 7018 i Trondheim (Ilsvika- og Skansenområdet).**
Det tar omtrent 5 minutter å fylle det ut, og det er helt frivillig og konfidensielt. Jeg vil ikke ha tilgang til e-postadressen din etter at du har sendt inn undersøkelsen, den er anonym.
Innsending av utfylt undersøkelse vil bli betraktet som ditt samtykke til å delta i undersøkelsen.
Jeg ville satt pris på om du kan fylle ut undersøkelsen så tidlig som mulig og senest 21. mars. Når som helst i undersøkelsen har du rett til å trekke svarene dine.
Innen 1. juni 2024 vil alle data som er samlet inn gjennom disse undersøkelsene, bli slettet. Inntil da vil den bli lagret på en passordbeskyttet sky.
Merk at det ikke finnes riktige eller gale svar, og dine meninger er av stor verdi for å bygge en bedre forståelse rundt mer vellykkede bynaturløsninger.
På forhånd takk for din deltakelse, og din hjelp til å utvikle masteroppgaven min.

Joanna Radkiewicz
Student i globalisering og bærekraftig utvikling
Institutt for geografi – NTNU, Trondheim

Hvis du har spørsmål, klager eller bekymringer angående hvordan forskningen utføres, kan du gjerne kontakte meg direkte, eller veilederne mine som er ansvarlige for forskningen min,
Martina Calovi og Hilde Nymoen Rørtveit, på følgende e-postadresser:

Joanna joannalr@stud.ntnu.no
Martina martina.calovi@ntnu.no
Hilde hilde.nymoen.rortveit@ntnu.no

Besøker eller bruker du Iladalen parken?

Number of submissions: **56**

Submissions	Count	% of submissions	
Yes	55	98.2%	98.2%
No	1	1.8%	1.8%

Hvis ja, angi hvor ofte, på skalaen fra 1 (sjelden) til 5 (daglig).

Number of submissions: **56** Average: **3.29** Median: **3**

Submissions	Count	% of submissions	
1	4	7.1%	7.1%
2	11	19.6%	19.6%
3	15	26.8%	26.8%
4	17	30.4%	30.4%
5	9	16.1%	16.1%

Hvis ja, hvordan tilbringer du tiden din illadalen parken?

Number of submissions: **56**

Submissions	Count	% of submissions	
Rusle (walking)	42	75%	75%
Går igjennom (passing through)	42	75%	75%
Trener (exercising)	5	8.9%	8.9%
Slapper av (relaxing)	33	58.9%	58.9%
Sosialisere (socializing)	18	32.1%	32.1%
Annet (other)	9	16.1%	16.1%

Angi hvor mye du verdsetter grønne områder i nabolaget ditt på skalaen fra 1 (svært lite) til 5 (mye).

Number of submissions: **56** Average: **4.88** Median: **5**

Submissions	Count	% of submissions	
1	1	1.8%	1.8%
2	0	0%	0%
3	0	0%	0%
4	3	5.4%	5.4%
5	52	92.9%	92.9%

Basert på det urbane grøntområdet i nabolaget ditt, er kommunes initiativ for å tilføre mer grønt ønskelig for deg?

Number of submissions: **56**

Submissions	Count	% of submissions	
Yes	55	98.2%	98.2%
I do not have an opinion	0	0%	0%
No	1	1.8%	1.8%

Annerkjenner du noen av fordelene som Iladalen park gir til nabolaget som fellesskap?

Number of submissions: **55**

Submissions	Count	% of submissions	
Yes	53	96.4%	96.4%
No	2	3.6%	3.6%

Hvis ja, vennligst oppgi dem.

Number of submissions: **44**

- friområde utenfor traffikert område
- Godt for dyreliv og folkeliv. Eldre og Barn
- Gir ro i sjelen
- Gå tur med venner, fin trimtur opp til Theisendammen
- Det gir historisk informasjon relatert til Iladalen. Det er en god inngang til gåtur i Iladalen
- Trivelig, fint sted for barn å leke.
- Socialising area, Meeting point
- Lokale fritidsområder, trygt å være fotgjenger, psykisk boost fra kontakt med natur
- Skaper møteplasser og mulighet for barna å være ute og kose seg med forskjellige aktiviteter.
- Mere sosialt fellesskap
- Ilabekken, fugleliv, trær og busker
- Gir uteområder til beboere uten balkong/hage. Lufting av hund.
- Møter kjente,møter andre som lufter hund.Hyggelig sted
- Sosialt og godt nabolag
- Folk er i bedre humør
- Friluftsområde en soldag
- Makes the area more attractive, makes the outdoors more accessible, makes it easier to socialize outside with more people
- Spesielt viktig med grønne områder i urbane strøk, og at Ilanekken renner gjennom parken er en ytterligere forsterkning av dette!
- Mulighet til rekreasjon i grønt område dersom man ikke har egen hage
- Fugleliv, vassing for hunden, folk koser seg i sola, turområde, vakkert
- Recreation area in the neighbourhood, people can meet there, children can play. Place to walk the dog, have a chat, relax.

- 1) Grønn lunge 2) Estetisk forskjønnende for området 3) Et flott uteareal for beboere i området som ikke har eget uteområde 4) Fint å ha piknik der 5) Lekeområde for barn 6) Luftested for hunder
- I walk my dog daily thru the park and often meet others both with and without dogs. Due yo my work situation this is often my social life. In which I most appericiate.
- Grønn lunge, aktiviteter i natur, kobling mellom urbane miljø og natur
- Lufte hund
- Restitusjon og trivsel
- Roligere nabolag. Mulighet for volleyball og annen aktivitet. Sted å slappe av på sommeren
- Avkobling. Naturopplevelse
- Det samles ofte grupper av mennesker for sosialisering, og mange naboer hilser på hverandre når de møtes på gåturer i parken.
- Sosialt møtested, kort vei til natur/grøntområde, barnevennlig, miljøvennlig for det lokale økosystemet
- turområdet. se på dyrelivet som inkluderer ender, bever, grevling og rev. mye fine fugler. har hunder som bader og leker i elva nesten daglig. plukker blomster og snakker med venner. det er et fint samlingspunkt.
- Lovely for recreation and relaxing
- Et sted å være sammen, uten å kjenne noen.
- Jeg har hund og møter ofte andre med hund i parken - både planlagt og uplanlagt. På denne måten, møter jeg nye folk som bor i nabolaget, og vedlikeholder forholdet med de jeg kjenner fra før av.
- Møter andre folk, lettere å komme seg ut
- Det er en sosial møteplass, brukes til sportslige aktiviteter, bra for barns lek og utforsking, nærhet til natur i nabolaget, historisk betydning i et nærmiljøperspektiv
- Meeting fellow dog walkers, and good for mental health
- Er en grønn lunge, gir et godt nærmiljø, fint for småbarn med tilgang til park med blomster og fugler
- Trivsel, fri følelse, avslapning, enkelt å ha med barnebarn
- En plass å være uten biler og en plass å lufte hund
- Vollyball banen, grønt og friskt areal litt unna biltrafikken, fine gressarealer for en piknikk
- Rennende vann, mye å utforske, er ikke en «steril» park
- Vi møter mange naboer, venner og ukjente vi kan se og prate med. Avtale møter osv.
- Være vitne til biologisk mangfold, se dyr og fugler i vill tilstand

Vet du at Iladalen park har flere klimatilpasningsfunksjoner ?

Number of submissions: **55**

Submissions	Count	% of submissions	
Yes	14	25.5%	25.5%
No	41	74.5%	74.5%

Hvis ja, tror du det oppfyller målet?

Number of submissions: **23**

Submissions	Count	% of submissions	
Yes	15	65.2%	65.2%
No	8	34.8%	34.8%

Forbedrer Iladalen park områdets gangbarhet?

Number of submissions: **56**

Submissions	Count	% of submissions	
Yes	52	92.9%	92.9%
I do not have an opinion	3	5.4%	5.4%
No	1	1.8%	1.8%

Forbedrer Iladalen park områdets estetikk?

Number of submissions: **56**

Submissions	Count	% of submissions	
Yes	53	94.6%	94.6%
I do not have an opinion	2	3.6%	3.6%
No	1	1.8%	1.8%

Hvordan føler du deg når du besøker parken, eller bruker den til rekreasjon?

Number of submissions: **49**

- avslappet
- En fin naturopplevelse
- Føler godt,ser årstidene rundt meg
- Avslappet

- Avslappet
- Bra
- Relaxed, calm
- Jeg har utsikt til grønt og fjorden hjemmefra, men syntes likevel at parken gir ro.
- Rolig, fredelig, glad
- Veldig fint området som inviterer til koselig samvær.
- Rolig
- Fornøyd
- Relaxed.
- Stolt av å bo i Ila
- Avslappet
- Blir i bedre humør
- Bra
- I feel relaxed and more grounded
- Grønne lunger senker pulsen og øker oksygenopptak - jeg blir iallefall lykkeligere :)
- Glad og avslappet
- Happy
- Avslappet og fornøyd
- Love it. I live right next to it and enjoy the view ovwr the park
- Glad, nysgjerrig, lett
- Flott og fri
- Avslappet
- Avslappet
- Gir ro og glede. Får naturen tettere innpå. Litt farge i nabolaget.
- Glad
- Avslappet, nærmere naturen, lykkelig
- Rolig
- føler ro og blir glad av det.

- Happy
- Bra
- Ilaparken er er Trivelig sted, på tvers av generasjoner.
- Jeg føler meg veldig avslappet og glad.
- Nyter, ser, opplever, slapper av
- Glad
- Det gir ro og minsker stress, gir en umiddelbar nærhet til naturen
- Calm
- Jeg føler meg avslappet og sildring fra åpen bekk gir ro. Vi helt ved Iladalen, og har grøntområdene som vår nabo. Veldig heldige!
- Nautral
- Svært tilfreds
- Ro, bekken som suser igjennom og gir liv av andre dyr
- Avslappet og glad
- Avslappet, glad
- Har det bra.
- Heldig
- Når brukerne respekterer biomangfoldet; veldig bra. Ved misbruk; mindre bra

På skalaen fra 1 (helt uenig) til 5 (helt enig), hvor enig er du i påstanden: "Den Iladalen parken forbedrer velværen i nabolaget"?

Number of submissions: **56** Average: **4.77** Median: **5**

Submissions	Count	% of submissions	
1	0	0%	0%
2	1	1.8%	1.8%
3	1	1.8%	1.8%
4	8	14.3%	14.3%
5	46	82.1%	82.1%

Tror du at Iladalen park påvirker din livskvalitet og velvære positivt?

Number of submissions: **55**

Submissions	Count	% of submissions	
Yes	53	96.4%	96.4%
I do not know	2	3.6%	3.6%
No	0	0%	0%

9.3 Appendix 3. Google Earth code editor code for NDVI results from 2004 and 2023

```
var filteredDate1 = Landsat5
    .filterDate('2004-06-18', '2001-08-24')
    .filterBounds(IladalenPark)
    .map(applyScaleFactors)
    .map(fmask);
print('Filtered Image Collection - Date 1:', filteredDate1);

var filteredDate2 = Landsat8
    .filterDate('2023-06-04', '2023-09-12')
    .filterBounds(IladalenPark)
    .map(applyScaleFactors)
    .map(fmask);
print('Filtered Image Collection - Date 2:', filteredDate2)

function fmask(img) {
  var cloudShadowBitMask = 1 << 3;
  var cloudsBitMask = 1 << 5;
  var qa = img.select('QA_PIXEL');
  var mask = qa.bitwiseAnd(cloudShadowBitMask)
                .eq(0)
                .and(qa.bitwiseAnd(cloudsBitMask).eq(0));
  return img.updateMask(mask);
}

function applyScaleFactors(image) {
  var opticalBands = image.select('SR_B.').multiply(0.0000275).add(-0.2);
  var thermalBands =
image.select('ST_B.*').multiply(0.00341802).add(149.0);
  return image.addBands(opticalBands, null, true)
              .addBands(thermalBands, null, true);}



var medianDate1 = filteredDate1.median();
```

```
var medianDate2 = filteredDate2.median();

var ndviDate1 = medianDate1.normalizedDifference(['SR_B4', 'SR_B3']);

var ndviDate2 = medianDate2.normalizedDifference(['SR_B5', 'SR_B4']);
Map.addLayer(medianDate1, {min: 0, max: 255, bands: ['SR_B3', 'SR_B2',
'SR_B1']}, 'True Color - Date 1');
Map.addLayer(medianDate2, {min: 0, max: 255, bands: ['SR_B4', 'SR_B3',
'SR_B2']}, 'True Color - Date 2');

Map.addLayer(ndviDate1, {min: 0.1, max: 1, palette: ['FFFFFF', 'CE7E45',
'DF923D', 'F1B555', 'FCD163', '99B718', '74A901',
    '66A000', '529400', '3E8601', '207401', '056201', '004C00', '023B01',
    '012E01', '011D01', '011301']}, 'NDVI - Date 1');
Map.addLayer(ndviDate2, {min: 0.1, max: 1, palette: ['FFFFFF', 'CE7E45',
'DF923D', 'F1B555', 'FCD163', '99B718', '74A901',
    '66A000', '529400', '3E8601', '207401', '056201', '004C00', '023B01',
    '012E01', '011D01', '011301']}, 'NDVI - Date 2');

var clippedMedianDate1 = medianDate1.clip(IladalenPark);
var clippedMedianDate2 = medianDate2.clip(IladalenPark);
var clippedNdviDate1 = ndviDate1.clip(IladalenPark);
var clippedNdviDate2 = ndviDate2.clip(IladalenPark);

var exportRegion = IladalenPark;
Export.image.toDrive({
  image: clippedMedianDate1,
  description: 'True_Color_Date_1',
  folder: 'NDVIfromGEE',
  scale: 30,
  region: exportRegion
});

Export.image.toDrive({
  image: clippedMedianDate2,
  description: 'True_Color_Date_2',
  folder: 'NDVIfromGEE',
  scale: 30,
  region: exportRegion
});
```

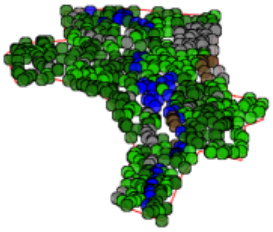
```
Export.image.toDrive({
  image: clippedNdviDate1,
  description: 'NDVI_Date_1',
  folder: 'NDVIfromGEE',
  scale: 30,
  region: exportRegion
});

Export.image.toDrive({
  image: clippedNdviDate2,
  description: 'NDVI_Date_2',
  folder: 'NDVIfromGEE',
  scale: 30,
  region: exportRegion
});

var ndviStatsDate1 = ndviDate1.reduceRegion({
  reducer: ee.Reducer.minMax(),
  geometry: IladalenPark,
  scale: 30,
  maxPixels: 1e9
});

var ndviStatsDate2 = ndviDate2.reduceRegion({
  reducer: ee.Reducer.minMax(),
  geometry: IladalenPark,
  scale: 30,
  maxPixels: 1e9
});

print('NDVI Statistics - Date 1:', ndviStatsDate1);
print('NDVI Statistics - Date 2:', ndviStatsDate2);
```

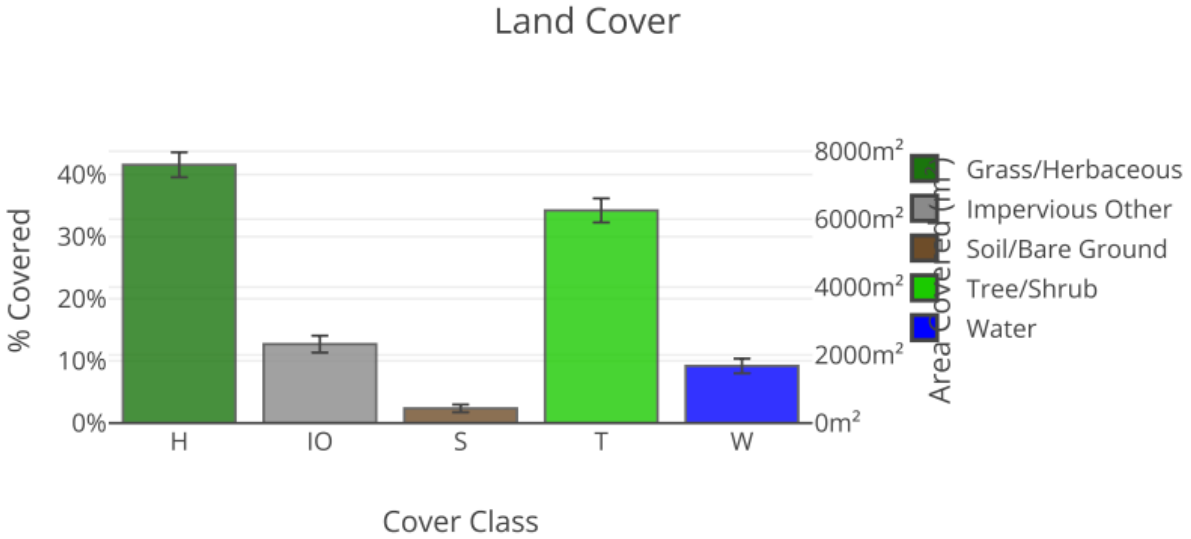
9.4 Appendix 4. iTree report

i-Tree Canopy

Cover Assessment and Tree Benefits Report

Estimated using random sampling statistics on 4/3/2024





Abbr.	Cover Class	Description	Points	% Cover ± SE	Area (m²) ± SE
H	Grass/Herbaceous		249	41.57 ± 2.01	7600.92 ± 368.20
IO	Impervious Other		76	12.69 ± 1.36	2319.96 ± 248.66
S	Soil/Bare Ground		14	2.34 ± 0.62	427.36 ± 112.87
T	Tree/Shrub		205	34.22 ± 1.94	6257.79 ± 354.47
W	Water		55	9.18 ± 1.18	1678.92 ± 215.74
Total			**599**	**100.00**	**18284.95**

Tree Benefit Estimates: Carbon (Metric units)

Description	Carbon (t)	±SE	CO_2 Equiv. (t)	±SE	Value (NOK)	±SE
Sequestered annually in trees	1.91	±0.11	7.02	±0.40	3,172 NKr	±180
Stored in trees (Note: this benefit is not an annual rate)	48.09	±2.72	176.33	±9.99	79,671 NKr	±4,513

Currency is in NOK and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Amount sequestered is based on 0.000 t of Carbon, or 0.001 t of CO_2, per m²/yr and rounded. Amount stored is based on 0.008 t of Carbon, or 0.028 t of CO_2, per m² and rounded. Value (NOK) is based on 1,656.71 NKr/t of Carbon, or 451.83 NKr/t of CO_2 and rounded. (Metric units: t = tonnes, metric tons, m² = square meters)

Tree Benefit Estimates: Air Pollution (Metric units)

Abbr.	Description	Amount (kg)	±SE	Value (NOK)	±SE
CO	Carbon Monoxide removed annually	1.00	±0.06	16 NKr	±1
NO2	Nitrogen Dioxide removed annually	23.97	±1.36	435 NKr	±25
O3	Ozone removed annually	112.23	±6.36	1,781 NKr	±101
SO2	Sulfur Dioxide removed annually	9.85	±0.56	64 NKr	±4
PM2.5	Particulate Matter less than 2.5 microns removed annually	9.20	±0.52	4,836 NKr	±274
PM10*	Particulate Matter greater than 2.5 microns and less than 10 microns removed annually	32.33	±1.83	1,022 NKr	±58
Total		**188.58**	**±10.68**	**8,154 NKr**	**±462**

Currency is in NOK and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Air Pollution Estimates are based on these values in kg/m²/yr @ NKr/kg/yr and rounded:
CO 0.000 @ 16.01 NKr | NO2 0.004 @ 18.16 NKr | O3 0.018 @ 15.87 NKr | SO2 0.002 @ 6.47 NKr | PM2.5 0.001 @ 525.92 NKr | PM10* 0.005 @ 31.62 NKr (Metric units: kg = kilograms, m² = square meters)

Tree Benefit Estimates: Hydrological (Metric units)

Abbr.	Benefit	Amount (kl)	±SE	Value (NOK)	±SE
AVRO	Avoided Runoff	5.20	±0.29	103 NKr	±6
E	Evaporation	1,424.31	±80.68	N/A	N/A
I	Interception	1,431.69	±81.10	N/A	N/A
T	Transpiration	1,280.59	±72.54	N/A	N/A
PE	Potential Evaporation	5,833.21	±330.42	N/A	N/A
PET	Potential Evapotranspiration	4,545.77	±257.49	N/A	N/A

Currency is in NOK and rounded. Standard errors of removal and benefit amounts are based on standard errors of sampled and classified points. Hydrological Estimates are based on these values in kl/m²/yr @ NKr/kl/yr and rounded:
AVRO 0.001 @ 19.74 NKr | E 0.228 @ N/A | I 0.229 @ N/A | T 0.205 @ N/A | PE 0.932 @ N/A | PET 0.726 @ N/A (Metric units: kl = kiloliters, m² = square meters)

About i-Tree Canopy

The concept and prototype of this program were developed by David J. Nowak, Jeffery T. Walton, and Eric J. Greenfield (USDA Forest Service). The current version of this program was developed and adapted to i-Tree by David Ellingsworth, Mike Binkley, and Scott Maco (The Davey Tree Expert Company)

Limitations of i-Tree Canopy

The accuracy of the analysis depends upon the ability of the user to correctly classify each point into its correct class. As the number of points increase, the precision of the estimate will increase as the standard error of the estimate will decrease. If too few points are classified, the standard error will be too high to have any real certainty of the estimate.

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