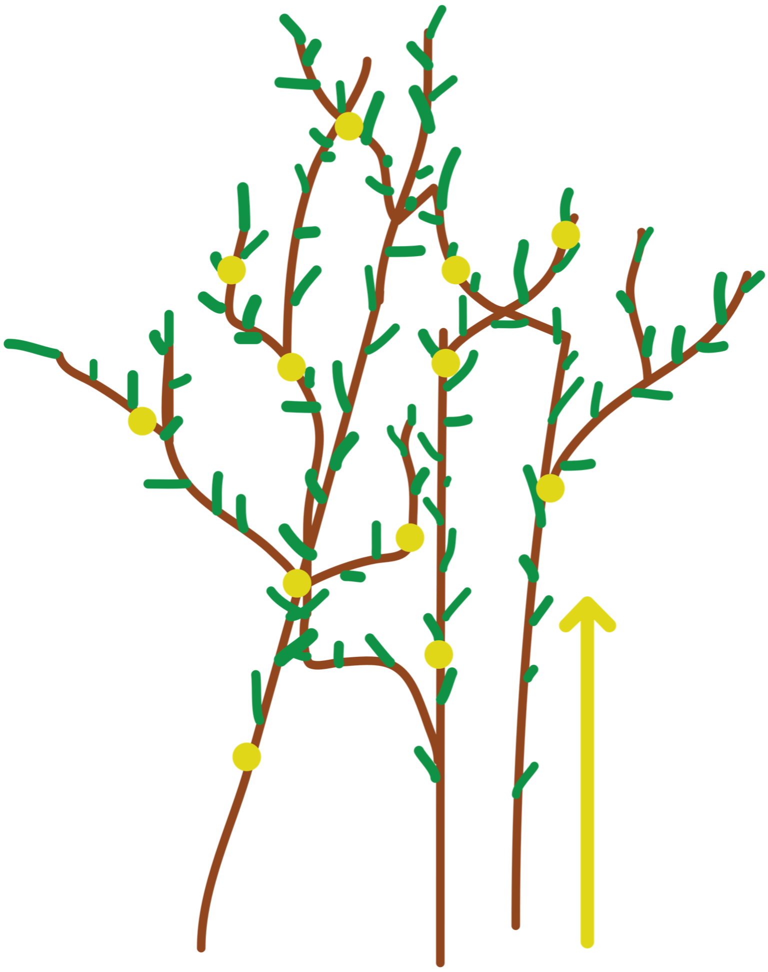
Assessing the SVIKT project

Implemented nature-based solution in Järfälla municipality



Emmy Strömsten
Lukas Nygren
SUPD, AG2809, KTH
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Abstract / Sammanfattning

English

This study aims to investigate the process, results and continuation of using salix as a nature-based solution for cleaning the soil from toxins (the process of phytoremediation) in Skälby, Järfälla. The project, named SVIKT, is a pilot project exploring alternative solutions for cleaning soil from toxins, while also capturing carbon and improving biodiversity in the area. We have collected data from interviews, site visits, literature reviews and analysis of the main actors' descriptions of the project. The report thus presents the information gathered from the main actors and then assesses the challenges and successes of the SVIKT project through external research. This report thereby highlights both the potentials and the complexities in implementing a monoculture of deciduous trees to perform phytoremediation. Furthermore the paper contributes with the lessons learned, future scenarios for the site and recommendations for similar projects in the future. Key findings of the research emphasize the complexities in speaking of carbon capture when the biomass has to be burned at a later stage in the process. Furthermore, the research highlights how salix in phytoremediation can pose an increased risk of exposure of contaminants into wildlife and nearby areas caused by the absorption of the contaminants in the leaves. However, the roots system and considerable biomass of the salix in the case of SVIKT has successfully prevented the spreading of contaminants into water bodies, thus decreasing risks of eutrophication, erosion, floodings and heat waves in the area. Hence, SVIKT can be considered as a nature based solution more successful in the department of climate change mitigation rather than phytoremediation when looking into the results of the project as of now. The study therefore emphasizes the complex and unexpected benefits and risks of using salix as a nature based solution, meanwhile encouraging the initiative of striving towards a better tomorrow.

Svenska

Denna studie syftar till att undersöka processen, resultaten och projektets framtid.Vi undersöker därmed användningen av salix som en naturbaserad lösning för att rena marken från gifter (processen kallas fytoremediering) i Skälby, Järfälla. Projektet, kallat SVIKT (Smarta Växter I Klimatets Tjänst), är ett pilotprojekt som utforskar alternativa lösningar för att rena marken från gifter. Projektbeskrivningen understryker de multifunktionella egenskaperna av salix, och berör bland annat kolinlagring och ökad biodiversitet samt skydd mot översvämning och erosion i området. Vi har samlat in data från intervjuer, platsbesök, litteraturstudier och analys av huvudaktörernas beskrivningar av projektet. Rapporten presenterar därmed informationen som samlats in och bedömer sedan utmaningarna och framgångarna med SVIKT-projektet genom extern forskning. Således belyser denna rapport både potentialerna och komplexiteterna vid implementering av en monokultur av lövträd för att utföra fytoremediering. Dessutom bidrar rapporten med lärdomar, framtidsscenarier för platsen och rekommendationer för liknande projekt. Resultatet från studien betonar komplexiteten när det gäller att tala om kolinlagring i fall då biomassan måste brännas vid en senare tidpunkt i den parallella fytoremidieringsprocessen. Dessutom belyser studien hur salix vid fytoremediering kan innebära en ökad risk för spridning av föroreningar till vilda djur och närliggande områden på grund av upptaget av föroreningar i löven på träden. Dock har biomassan reducerat risken för värmeböljor i området och dess rotsystem framgångsrikt förhindrat översvämningar, och i sin tur spridning av föroreningar till vattendrag, vilket minskar riskerna för övergödning. Därför kan SVIKT betraktas som en naturbaserad lösning som är mer effektiv sett till minskandet av effekter från klimatförändringar, när man ser till resultaten av projektet hittills. Studien betonar således de komplexa och oväntade fördelarna och riskerna med att använda salix som en naturbaserad lösning samtidigt som den uppmuntrar initiativet att sträva mot en bättre framtid.

Acknowledgement

We would like to thank all those who took time out of their day to contribute with their honesty, transparency and knowledge of the SVIKT project. We would like to give a special acknowledgement to Clean Nature for their guidance and efforts to contribute with a lot of the data for this project. We have learned a lot during the process and hope that our efforts can be helpful for the municipality, and for other up and coming similar projects in the future. We would also like to say thank you to our classmates and supervisor who supported us through this study, with great input and cheerful company. And lastly, the municipality for giving us this opportunity.

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All the best!

Emmy and Lukas

Table of contents

1. Introduction

According to the most recent report from the World Meteorological Organization (WMO, 2023) the last decade (2011-2020) has been the warmest decade on record. The report also highlights that the levels of greenhouse gasses in the atmosphere have continued to increase. Trees and plants provide essential functions we have to counteract the increase in CO_2 (UN, n.d.). Not to mention, their importance for biodiversity and well-functioning ecosystems and the importance for agriculture (ibid.). However, as the population increases, the foundation for plants and crops survival, sufficient soil qualities, has become further at risk due to human activities and climate change (FAO, 2022). Järfälla municipality, located in the north of the Stockholm region, Sweden, is planning for an increase of 30,000 inhabitants. Moreover, a total of 18,000 new homes and 140 neighborhoods are planned by 2030 (Järfälla Kommun, 2014). Among urbanization, loss of ecosystems, microclimate, and biodiversity are being challenged. To target such issues new and innovative methods are needed. In recent years, nature-based solutions have become an increasingly emphasized solution, turning towards natural processes and multifunctionality to increase climate change mitigation against heat waves and flooding, or cleaning of humanly induced emissions and toxins (IPBES, 2019; Naturvårdsverket, 2021). Many of the natural resources that we take for granted in day to day life, and think of as renewable and endless are in fact not endless. Fertile soil is one of the resources to consider endless. With the lack of proper knowledge or care from previous and current industrial activities, soil pollution is an issue in today's planning environment (Personal communication R3, 2023).

The traditional way of getting rid of polluted soil is to excavate the polluted soil masses and take them to landfill areas or to use counteractive chemicals to target the pollution (Osman, 2014). The positive aspect of the conventional method is that the pollutants and the polluted soil is removed rapidly, which might be crucial in order to be able to use the land. However, in the conventional tradition one is not restoring the soil qualities but rather removing it. This is a distinct consideration as quality soil is a limited and crucial product for functioning ecosystems and agriculture. Furthermore, the traditional process is costly and releases a significant amount of emissions in transportation and storage (Hasselgren, 2008). Therefore it is of importance to investigate innovative alternatives aiming to restore soil qualities, which has been found in the SVIKT project in Järfälla municipality.

This study aims to investigate and assess the SVIKT project, a 2-year long innovative pilot project in Järfälla, using the tree species, salix, in the process of phytoremediation to extract pesticides and heavy metals from the ground (the process is visualized in Figure 3). The toxins are present as the site for the project is located on grounds of former plantation industries. The cleaning of the soil is highlighted through the description of the SVIKT project while increasing biodiversity, mitigating floods and functioning as carbon capture are additional benefits (Järfälla Kommun et al., 2023). The study aims to conclude main takeaways from the SVIKT project and the lessons learned. From the knowledge derived during the assessment, future scenarios will be presented and evaluated according to certain set targets derived during the assessment. The future scenario focuses on the continuation of the municipality managing the project, as the 2-year project was officially ended in November 2023. The assessment investigates increased bioremediation, and improved soil qualities and explores biodiversity enhancement and carbon capture in the SVIKT project. Thus, striving towards the UN Sustainable Development Goal 15 (Life on land) which states by 2030, to ensure the protection, restoration, and promotion of sustainable ecosystems, sustainably manage forests, and desertification, prevent and reverse land degradation, and stop the loss of biodiversity (UN, 2015). However, the study touches several other SDGs, since improving soil qualities is necessary for sustaining life (FAO, 2022).

From the aim and objective the following research questions were derived:

- What were the main steps in implementing the SVIKT project?
- What are the main outcomes and insights from the SVIKT project?
- How can the main insights from the SVIKT project be integrated into scenarios for the project continuation?

1. 3. Background

This section of the report will present the background needed in order to follow the discussions of the report further on. Key concepts will be explained and elaborated upon, with the intent of guiding the reader through the report.

1. 3. 1 The SVIKT project

The SVIKT project was initiated by Järfälla municipality in 2020, and is funded through innovation-research found from Vinnova. The project aims to cleanse the soil of former market garden grounds with high levels of toxins and heavy metals such as arsenic, lead and residues from pesticides. The scope of the project includes 40 000 plants of the salix-clones 'Tora' and 'Tordis' in a 1 hectare area between Byleden and Björkebyvägen seen in Figure 1 (Järfälla Kommun, 2023). Tora and Tordis is a mix between salix schwerinii and salix vimanalis, native in north east asia and is a popular cross of shrubs, however both types need to be planted in moist and wet soil (Jordbruksverket, 2019). The process of phytoremediation then includes harvesting the trees for incineration, but when this will happen is until today not specified (Personal communication R2, 2023). The site and the salix plantation can be seen in Figure 2, during different seasons.

Järfälla municipality highlights the risk of Bällstaån becoming contaminated in the event of increased flood risk due to climate change. The area for the project is located so that the runoff and excess water could potentially reach Bällstaån, and therefore cleansing this area is of priority (Järfälla Kommun, 2023). The listed benefits from the project are besides from the extraction of the toxins in the ground, CO_2 capture, mitigating heat stress and water flows, promoting biodiversity and increasing the public knowledge on climate change effects, and how they can be mitigated (Barkarby Science, 2023).To enhance biodiversity, the project also includes a sandbank solution aiming to attract pollinators and increase the levels of insects in the area. (Järfälla Kommun et al., 2023).

Figure 1. Left: Area for the project area between Barbaby and Skälby the SVIKT area. Right: The 2 planted areas, 1 hectare together. (maps from OpenStreetmap, 2023).

Figure 2. Left: Salix trees with leaves (Clean Nature, 2023)., Right: The site of the SVIKT project in January 2024.

1. 3. 2 Nature-based solutions

Nature Based Solutions (NBS) is an upcoming technology inspired by the natural functions and systems already found in nature (Naturvårdsverket, 2021). The idea of nature-based solutions was initially introduced by the International Union for Conservation of Nature (IUCN) to address climate vulnerabilities by optimizing the benefits of nature. These solutions tap into the potential of natural resources to tackle various societal and environmental challenges while minimizing emissions and conserving ecosystems. One of the main principles and selling points for NBS is that these solutions are cost effective and aim to replicate and make use of ecosystem services already provided by well-functioning ecosystems (Naturvårdsverket, 2021; Bocking, 2015). Nature-based solutions encompass a range of concepts, including green infrastructure, ecological engineering, and ecosystem-based adaptation, aiming to mitigate a wide range of issues such as climate change, food security, and disaster resilience in a cost-effective and sustainable manner (Gupta et al., 2020).

To understand the idea of NBS one of the key concepts is ‘Nature’, which is explained by Malm (2017) as every material and process independent of human interference meanwhile also shaping the foundation of human activities. Therefore, a significant challenge in the concept of nature-based solutions lies in understanding the ambiguity of the term and which solutions and systems can be described as "natural" (Malm, 2017).

1. 3. 3 Microorganisms, Mycorrhiza and soil quality

Soil is crucial for sustaining life on Earth. Microbes, as integral components of soil ecosystems, actively participate in building and maintaining soil structure and fertility. In ecological systems, fungi play a primary role as decomposers of organic waste materials through their enzymes (Wei, 2019). A diversity of microbes are of importance for ecological functions, and the foundation behind various ecosystems. According to Wang et al. (2018) soil properties are dependent on the nutrient cycle and decomposition of microorganisms such as mycorrhiza. However, these microorganisms are sensitive to changes and can cause significant nutrient leakage and lower plant growth if the symbiosis is aborted. Hence, Mycorrhizal functions already play a key role in cleansing soil from over-fertilization and thus a preventive measure for water contamination solution (Silwer, 2020). Mycorrhizal can also assist plants in removing toxins from the ground by various mechanisms, including forming a protective barrier around the root cells and producing certain compounds with the ability to bind with heavy metals, reducing their toxicity to the plant (Ibrahim, 2023).

Mycorrhizal is one of the most widespread and oldest symbiotic functions known on Earth, with a history dating back hundreds of millions of years in supporting algae colonizing land and becoming plants. Nevertheless, it was not until recent decades they were discovered (Silwer, 2020). Furthermore, many mycorrhizal species mainly grow in older untouched forests and are rarely found in secondary forests that have been replanted after deforestation (Djupström, 2022). Therefore, in areas where trees have a shorter lifespan, mycorrhiza is rare, to the extent that 341 mycorrhizal fungi are red-listed in Sweden (SLU Swedish Species Information Centre, 2022). Mycorrhiza fungus's vast root system furthermore helps bind soil particles, preventing erosion and enhancing water retention. Arbuscular mycorrhizal fungi help soil stick together by wrapping their roots around particles (Rillig, 2006). In addition mycorrhiza produces important proteins in the soil called glomalin (Yang, 2017). Moreover, fungi such as mycorrhiza can help decompose through its enzymes and release organic matter into the soil, providing a rich source of nutrients for plants and other microorganisms (Aislabie, 2023). Thus, increasing the breakdown of organic matter, influencing root growth and nearby microbes (Wei, 2019). Therefore, by improving soil aggregation through strengthened soil structure, the hydrological balance is strengthened, improving water retention (Rillig, 2006). Mycorrhizal extensive root networks furthermore contribute to carbon sequestration in soils, mitigating both climate change and ecosystem functions (Guijre, 2021).

Mycorrhizal can also assist plants in removing toxins from the ground by various mechanisms, including forming a protective barrier around the root cells and producing certain compounds with the ability to bind with heavy metals, reducing their toxicity to the plant (Ibrahim, 2023). However, mycorrhizal has enzymes important for composting and supporting plants in phytostimulation. Phytostimulation is the synergy between microorganisms such as mycorrhiza, facilitating degradation of the outputs from plants in a process of phytoremediation, cleaning soil from toxins (Osman, 2014). Mycorrhiza is a symbiotic association, whereupon the plant provides the fungus with sugars produced through photosynthesis, and in return, the fungus supports the plant in absorbing water and nutrients from the soil. In addition, the fungus also supports the plant against environmental stressors due to the fungi's vast network of fine threads (Ahammed, 2023).

In ecological systems, fungi play a primary role as decomposers of organic waste materials through their enzymes (Wei, 2019). Many mycorrhizal species mainly grow in older untouched forests and are rarely found in secondary forests that have been replanted after deforestation. (Djupström, 2022) Therefore, in areas where trees have a shorter lifespan, mycorrhiza is rare, to the extent that 341 mycorrhizal fungi are red listed in Sweden (SLU Swedish Species Information Centre, 2022).

As Mycorrhiza has been proven to significantly help plants absorb Phosphates/phosphorus, sulfur, and nitrate/nitrogen from the ground, many points towards Mycorrhiza being able to prevent excess nutrients from reaching water bodies. Mycorrhizal can also assist plants in removing toxins from the ground by various mechanisms, including forming a protective barrier around the root cells and producing certain compounds with the ability to bind with heavy metals, reducing their toxicity to the plant (Ibrahim, 2023). Mycorrhiza helps plants tolerate stressors such as heavy metal contamination and over-fertilization, although the same symbiotic functions can also support themselves against various external stressors, such as pathogens, droughts, heat, salinity, cold, and toxicity of pesticides, increasing the plants capacity for performing bioremediation (Bagyaraj, 2022). Mycorrhizal associations therefore have been proven to enhance plants' inoculum performance in contaminated soils. In other words, through strengthening the plants ability to withstand and recover from various stresses, the bioremediation of soil contaminated with heavy metals, organic pollutants, and other toxins can be improved (Sattiraju et al., 2023).

1. 3. 4 Phytoremediation

Phytoremediation can be classified into four categories, where the method used in the examined project in this study is phytoextraction, however for simplicity the term phytoremediation will be used when discussing the use of salix for binding soil contaminants in biomass. Thus it is the key idea of phytoremediation; using plants to extract and cleanse the soil from pollutants, such as heavy metals or harmful pesticides. The principle of phytoremediation technique is that plant roots either break the contaminant down in the soil or absorb and store the contaminant in the stems and leaves of the plants (Osman, 2014).

Phytoremediation uses plants, such as certain wild or cultivated crops, to absorb and store large amounts of harmful elements in their above-ground bodies. Some plants, known as hyperaccumulators, can take up large amounts of heavy metals, making up a significant portion of their weight. After a significant absorption of toxins, harvesting is needed, disposing of the now heavily polluted plant into ash, which is a fairly cost-effective solution. Furthermore plants with a lot of above-ground growth can be harvested multiple times in a season, without uprooting the whole plant. However, to finalize the phytoremediation process the root systems must be dissolved just as the rest of the plant, to secure the soil from re-gaining back some of the absorbed toxins (McIntyre, 2003).

Figure 3. The simplified phytoremediation process. (based on Järfälla Kommun et al., 2023; Osman, 2014).

There are many species suitable for phytoremediation, and different aspects of that (extraction, biodegradation etc.) among them different species of salix (Osman, 2014), which was used in the SVIKT project. Other species with phytoremediation qualities are listed by Osman (2014), and the list is included in the appendix to strengthen the reasoning in the assessment and scenarios further on.

1. 3. 5 Salix

Salix is suitable to be cultivated in all of Sweden, however, salix thrives particularly well in areas with large amounts of water and light conditions, with pH levels above 6 (Jordbruksverket, 2019). About 20% of salix species possess features crucial for biomass and contaminants accumulation. These include high biomass productivity, adaptability to new environmental conditions, relatively high resistance to soil impurities, and selective accumulation of contaminants. Salix has the ability to contribute towards biodiversity by providing resources for insects to feed while being a habitat for a variety of organisms. The dense structure of salix furthermore offers shelter for animals and nesting sites for birds. The fallen leaves also contribute to the nutrient cycling in the ecosystem (Weih, 2006).

The vast root network succeeds in keeping the soil in place, meanwhile absorbing excess water (Weih, 2006). Hence, operating as a preventive measure for the toxins in the ground in reaching other water bodies. Salix is a tree famous for its many differentiated benefits and its propagation qualities, which makes it suitable to use for large biomass generation in little time (ibid.). Weih (2006) also states that salix is commonly used for phytoremediation processes due to their ability to both tolerate and extract pollutants. Hence, salix can perform the extractive phytoremediation process, binding the pollutants in the tree stems and leaves.

Salix stands out for its effectiveness in biomass productivity compared to other plants, although in variation salix are known for their rapid growth and capabilities of nutrient and heavy metal absorption (Mleczek et al, 2018; Osman, 2014). Utilizing a salix plantation can serve as a means to cleanse the land, as the crops absorb nutrients and heavy metals that could otherwise contaminate watercourses or accumulate in the soil and food chain. Once the plantation is well-established, harvesting is generally conducted every three to four years over 20-25 years (Jordbruksverket, 2019). In a study on salix plantations for phytoremediation, significant uptake was noted, however, the author highlights that the results were based on the most vigorous and best-growing trees, suggesting varying outcomes in phytoremediation depending on their growth (Mleczek et al, 2018).

1. 3. 6 Limitations of Nature-based solutions and Phytoremediation

Restoring natural processes
As mentioned above nature-based solutions focus on implementing natural elements as a multifunctional solution, which therefore integrates with the concept of rewilding, restoring natural processes (Jørgensen, 2015). Bocking (2015) discusses the use of concepts in relation to nature, as the gap between the situated concept and how nature actually works is critical for the execution. Wilderness and the ideal of rewilding as a sustainable way forward is also highlighted as, for some, an ideal 'one size fits all'-solution and for some merely a way to impose western ideologies. Bocking also highlights how 'wild' areas and preserving nature are political topics, both in the land-use way, but also in the carbon capture and environmental conscious way (ibid).

Fraser et al. (2015) discusses the problematic ideas of making ecosystem restoration projects too focused on diversity of plants, rather than having a more holistic view of the system in depth, and neglect other important species that makes the system run smoothly. The tendency of rewilding projects appearing in practice with not enough research and site specific knowledge decreases the efficiency and could potentially harm more that it builds the system (ibid) .

Phytoremediation
While phytoremediation presents numerous advantages compared to traditional soil remediation methods, scratching the surface of phytoremediation reveals notable limitations. Hyperaccumulating plants tend to accumulate specific elements, making them less applicable to sites with various or mixed contaminants. Unfortunately, not all elements of concern in soils can be absorbed by plants, posing a challenge for global implementation. Additionally, using wild or non-indigenous plants for phytoremediation introduces specific risk assessment issues. (Osman, 2014) One critical concern of using phytoremediation is regarding its impact on wildlife and the food chain. Extensive research has established a clear connection between contaminant levels in the soil and plants and the concentrations of these compounds in the tissues of wildlife that feed in the affected area. This can lead to problems like kidney issues, neurological deficiencies, dental problems, to mention some, in animals living off plants in polluted areas. There's also a risk for predators that eat these exposed animals, spreading the toxicity into whole ecosystems. (Mcintry, 2003) Additionally, the accumulation of metals in plants can affect herbivores and pollinators in the food chain, which is a particular concern. As the plants themselves become toxic when growing in contaminated soil, the biomass becomes unsafe and hazardous to use (Mcintry, 2003; Osman, 2014).

Studies assessing the risks for wildlife on polluted sites show that small animals and birds, feeding on the insects in the area, are often the most exposed. According to McIntyre (2003) understanding and mitigating these ecological effects before constructing the sites could help manage potential effects on exposed species. Wildlife impacts from remediation are an evolving field, and predictions for a specific site are dependent on the specifics of wildlife species and the concentration of contaminants. However, prior assessments can guide the design of remediation sites to reduce exposures to wildlife. McIntyre (2003) proposes fences to hinder the entrance of all animals, or other barriers to prevent spreading.

1. 4 Methodology

The methodological approach for the assessment of the SVIKT project used triangulation of different methods to acquire the best understanding possible (Bryman, 2014). The triangulation process includes gathering information about the same or similar topic from different sources, and different types of sources (ibid.). The intent of this approach is to be able to see different nuances in different data sets, and hence generate a more nuanced understanding of a phenomenon investigated. Data regarding the SVIKT project was collected by interviews with different stakeholders, as well as finding information through their websites, and from the official project progress report released by the actors.

The research process was iterative, as new discoveries have led to other paths than what was perhaps expected in the beginning. Explained by Bryman (2014) this is a natural part of an inductive research approach, as theory, or in the case of this report main takeaways or possible future guidelines and scenarios, is formulated through observations and findings (ibid.). On the other hand, the research was carried out deductively, as the project is assessed through the glasses of theory, literature, and the knowledge gathered during the assessment. The iterative process of the assessment is what has made the research rich in learning, but also challenging in the way of delimiting the research to fit the scope of the report and the assignment. Combining an inductive and deductive research approach is called abductive research, which means that the theoretical framework can be altered before, during and after the data collection (Dubois & Gadde, 2002).

1. 4. 1 Case study

The study is built around the specific case of the SVIKT project. A case study enables a thorough investigation of a phenomenon within its natural context (Creswell et al., 2007). The case study of the SVIKT project is used to learn about the process of phytoremediation in practice, and it highlights the challenges and benefits of it. Understanding the concept in a situated case is one of the main reasons for the use of case studies in scientific research (Denscombe, 2009; Flyvbjerg, 2006), and why the case of the SVIKT project could potentially contribute to broader knowledge on the phytoremediation process.

1. 4. 2 Interviews

In this report, data has been collected from two semi-structured qualitative interviews with the main stakeholders in the project and one unstructured interview with an expert- researcher within soil qualities. The choice of constructing qualitative interviews was done to gain in depth information about the project, complexities understand the overall process and main challenges. Semi-structured interviews were chosen for their suitability, permitting participants to freely express their perspectives on the project process and achievements and challenges that they faced. Data gathering involved recording the interviews and using open coding to identify relevant indicators for directing the study towards and furthermore direct our literature review towards (Scheyvans, 2014). The questions were prepared beforehand and structured in an, as previously mentioned, open-ended way, which is good to retrieve as much information as possible, while still sticking to the topic of discussion (Heyink & Tymstra, 1993).

Ensuring a safe environment for participants to open up about their experiences is crucial for obtaining valid results. Prior to the interviews, the participant gained information about our research aim and consent to record was asked. An interview guide was formulated in consideration of the study's aim and research questions prior to the interview, see appendix. The interviews followed a basic set of questions while allowing participants to influence the direction of the discussions.

We conducted 3 interviews in total. The first interview was conducted with the CEO of Clean Nature and the second was conducted with the project leader in Järfälla municipality. Barkarby Science is listed as the communicator of the results of the project on the municipal website (Järfälla Kommun, 2023). Barkarby science was also contacted to comment on the project process and issues but as Barkarby science referred to Clean Nature to answer these questions, the choice was made not to pursue an interview with them. Instead, the third interview was conducted with a researcher at KTH with insight about soil quality, to be able to gain insights from an independent actor. The third interview was however structured differently as it was partly separated from the SVIKT project, but we still discussed the site specific challenges relevant to the case.

When identifying interviewees relevant to the project and the topic the main place to look was the actors and people involved in the project, where we got positive responses and could easily schedule interviews and have open discussions to learn about and reflect upon the project. However, when trying to contact experts with knowledge on related topics to the project such as biodiversity, phytoremediation and ecosystem services, they responded that they do not have enough expertise and knowledge on the topic. This required us to start searching for literature that could help us fill our knowledge gap.

1. 4. 3 Literature review

For this study different types of literature reviews were conducted. This was done in an iterative learning process where information and new discoveries have led to further research, resulting in some research not being of as much use as expected. This is also because the take on the assessment of the SVIKT project has changed during the process and the writing of this report. A challenge that appeared was that the literature reviews in the early stages of the study on Rewilding and Mycorrhiza did not hold as much relevance as expected, especially for the rewilding case and for the assessment of the SVIKT project as a whole. The challenge was tackled through extended research during the process of the assessment, especially on phytoremediation, salix and other related topics which were not covered in the main literature reviews. It was later on discovered that the use of mycorrhiza does in fact have larger relevance, which is why the search phrase presented further on includes both mycorrhiza and salix.

We chose to focus on and learn about mycorrhiza on a wider scale, to enable a better search for appropriate articles. In a first stage we started out researching projects testing different species in regards to mitigation to climate change challenges, to see what projects and information has been produced. The literature consists of scientific articles and reviews. A literature search was conducted in the Scopus database and on GU supersearch using search words such as mycorrhiza, toxins in the ground, and multifunctionality. We then found out there was a name for this specific function of fungus-cleaning soil called mycoremediation, which henceforth became a part of the search.

This resulted in the search phrase, which was then used in the Scopus and GU database: (Mycorrhiza OR Fungus OR Salix OR nature based-solutions) AND (Plants OR Soil OR Remediation OR Phythoreremidation OR mycoremediation OR Toxins OR Bioremediation) OR (Multifunctionality OR functions OR limitations OR process) OR (SWEDEN OR Project OR biodiversity)

Regarding the literature review of rewilding, the topic proved to, as mentioned before, not hold as much relevance for the general scope of the assessment but was useful when conducting the scenarios. The knowledge collected through the process of that literature review was kept in mind all through though. Influences from articles discovered through the process of understanding rewilding might have influenced the process of steering the assessment, which is why the method for conducting that literature review is included in this report as well.

Articles were searched for on Google Scholar, as it is a large international database of academic publications. The search words were chosen based on the chosen field of the study, and using the following chain; (“*wilding” OR “rewild*”) AND (“ecosystem*”) AND “resilience” AND “principles”. The first search result was a review of the science field of rewilding principles, and Carver et al. (2021), the authors of the paper, organized workshops and gathered input from rewilding experts with the intent to capture a definition and; as the title says, present “Guiding principles for Rewilding”. The paper includes 10 rewilding principles, and the articles chosen for the literature review is based on the main referred articles from Carver et al. (2021), which are mainly related to the case of the SVIKT-project in Järfälla municipality. Due to the limitations in time and scope of the assignment the key principles from their first sorting which were found to be most relevant were chosen for further guidance. The chosen key principles, and the publications related to them were searched for separately on KTH Primo and the availability and relevance resulted in 7 articles. These were the main sources of understanding rewilding, and the use for that knowledge was mostly useful when discussing and presenting the scenarios for future development in the results of this report.

1. 4. 4 Reviewing project specifics

We moved on to focus on gaining insights of the SVIKT project, where information was collected from the stakeholder’s webpages and the data of the interviews. The information on the SVIKT project presented in the background section of the report is mainly found through the webpages of main stakeholders, Barkarby Science and Järfälla municipality. Data on the progress/results of phytoremediation for the SVIKT project was collected from Cleannature's independent analysis of the salix. A report on the gathered experiences and evaluation of the project was released in December 2023, which has been studied for further insight and information on the specifics of the projects, as understood by the authors of which we have interviewed two out of the three. Looking at the report in question is useful in the aspect of seeing how the project and the results are communicated and achieve a broader understanding of the specifics of it.

1. 4. 5 Construction of scenarios

We have used the principles of normative preserving scenario construction, for its suitability of seeking efficient solutions available in current context to achieve certain goals (Börjeson, 2006). The option of backcasting, starting at the point of achieving long-term goals and then finding pathways of events and decisions to arrive there, was proven difficult as there are certain fixed boundaries of the project and municipality, such as the time-span and the funding provided by Vinnova. Therefore the choice was made to set the starting point from where we are today, to see which option could be available in meeting set goals (Börjeson, 2006).

According to Börjeson (2006) normative preserving scenarios, serves to determine how a particular target can be met efficiently. This type of approach is common in regional planning, where the initiation of a new plan typically involves a set of targets encompassing environmental, social, economic, and cultural factors. Planners then assess and make judgments on the most efficient path to achieve specific targets. This identified path can be considered a normative preserving scenario, aimed at "satisfying" goals rather than optimizing (Börjeson, 2006). Therefore we made the choice to focus on the existing solutions of today and not incorporate new technologies still being developed.

In constructing a normative preserving scenario, we aimed at using the tools available today to reach specific social and environmental dimensions for the municipality. The first scenario aims at reviewing the social and environmental benefits of continuing the project as planned. The second scenario, regarding mycorrhiza, was based out of the literature review of mycorrhiza and mycoremediation, applying the knowledge gained out of research to assess the possible benefits of implementing mycorrhiza to effectivize the phytoremediation of the salix. The third scenario was based on the literature review of rewilding, constructing a scenario whereby human interference is minimized. The last scenario was constructed to investigate which social benefits could be met by creating a learning environment of nature based solutions. To explore future scenarios we brainstormed and clustered similar ideas, and by grouping similar topics and situations the scenarios were decided upon, and then evaluated and discussed.

1. 4. 6 Targets for evaluation of the scenarios

When constructing targets for the scenarios, our aim was to present a visualization of how the different scenarios would potentially perform. Therefore the targets should not be viewed as scientifically proven or measured in this case, but seen as a pedagogical tool for what can be improved or be lost in the different scenarios. The targets are based on the situation today. It includes the targets communicated within the SVIKT project: ‘Carbon capture’,’ biodiversity’ and ‘phytoremediation’. As there have been difficulties in growth for some of the salix we added, ‘plant resilience’, referring to the ability of a plant to withstand and recover from various stresses. Furthermore, to be able to visualize the local losses if the biomass is removed or strengthened we added ‘erosion’, ‘flooding’ and’ heatwave’s. Lastly we added targets for the possibilities in the future, such as ‘increased educational opportunities’ and ‘possibilities for a new project’, as this was something that the municipality desired according to R2 (Personal communication, 2023).

1. 4. 7 Site visit

A site visit was made to the plantations in Skälby on the morning of 9th of January 2024, as site assessments are valuable for gathering information about the area and evaluating through observation (Lawrenz et al., 2003). The main purpose of this site visit was to conduct an investigation of the current state of the salix and investigate the presented information on site. The visit of the residential area was explored on foot. During the site visit we collected data in the form of pictures which will be presented in the report.

1. 4. 8 Data analysis

In writing the results of the study, we summarized and transcribed data from the interviews, site visit and project specifics into themes which could answer our research questions regarding the process, challenges and achievements of the project. The themes summarized were salix in phytoremediation process, project process, expected results, results. As new information and data was collected we researched that specific topic to put in a context of a small literature-review about the phenomenon, which is found in the background. For example, if we gained information about expected results of salix and its functions we made sure to gain more sources and perspectives. The results are then summarized and categorized in the "lessons learned" and later on analyzed in the "analysis of the results" together with the knowledge gained from the literature studies. Then we performed a cross-analysis of the data, involving comparing data or information from the different sources and perspectives to identify patterns, relationships, or trends(Ladany et al., 2012). This type of analysis was done to gain a comprehensive understanding of a complex phenomenon by considering various factors simultaneously, as different perspectives and sources highlight different challenges and takeaways of the SVIKT project. The same process of cross-analysis was used in constructing the scenarios, using the themes and main takeaways recognized from the results and the knowledge gained by the literature studies.

2. Results

The following section presents the results from the assessment of the SVIKT project, using the data conducted from interviews and project specifics from the main actors.

2. 1 Process behind the SVIKT project

According to R2 (Personal communication R2, 2023) the project was initially planned to be focused on carbon capture, but due to the presence of toxins in the ground chosen for the project site the target was broadened towards also cleaning the soil of toxins. Therefore, the project leader, due to the role as chemical expert of the municipality, got involved after the change was made to focus on contaminants of the area (ibid.).

According to the project report (Järfälla Kommun et al., 2023) the process to find a suitable location involved collaboration with officials from various parts of the municipality (urban development and parks and streets). This process was led by the Sustainable Development Unit, Department of Urban Development at Järfälla municipality, whereby consideration of various interests of the land areas was discussed. In these early stages a municipal ecologist and a forester were included in the project to provide knowledge about municipal land management and ecology. In this process they changed the current plan to plant bees as it might affect the wild bees in the area. Instead the decision was made to implement a sandbank to increase the amount of insects and animals in the area, hence increasing biodiversity. This was considered a success factor according to the report (ibid.). R1 explains that salix serves both as a habitat, shelter and as food for a numerous amount of insects and animals, therefore serving important functions for the local ecology and biodiversity. Furthermore, the use of Salix was decided upon early in the process, and other species or a combination of different species were not considered for the SVIKT project (Personal communication R1, 2023).

The SVIKT project was posed with challenges at an early stage. R1 (Personal communication R1, 2023) explains that the soil was far from sufficient for plantations, being filled with garbage and industry remains, which resulted in the project being delayed.

2. 2 Results of the SVIKT project

In the project report (Järfälla Kommun et al., 2023) the main actors highlights one anticipated negative effects of climate forests in residential environments regarding safety of the residents: "Within the project, a couple of potential conflicts of interest related to the establishment of climate forests in built environments were identified. There is a risk of reduced perceived safety and difficulties in utilizing the area for an extended period in densely populated communities." (ibid., 2023. p. 6, translated to English,). However, the resident seems to have a positive opinion towards the project, as minimal complaints have been received (ibid.).

The phytoremediation process is proven to be initiated, although operating at a slower speed than expected. In the data-analysis of the testing of salix stems and leaves, one can see absorption in the salix of different pesticides and heavy metals. The exact uptake can be found in the appendix. In the results from the performed analysis, one can see both the leaves and the root mass showing a significant absorption of heavy metals and pesticides. Furthermore as the trees continue to grow these numbers will increase. R1 (personal communication, 2023) points towards the full capacity of the phytoremediation to show the full results of phytoremediation in 10 years.

Soil samples were also taken at five sampling points both before the plantation of salix and 18 months after. The results of those soil samples revealed a slight increase of concentration of substances according to the report. However, the report highlights that there could be several reasons behind this, such as the pollutants not being evenly distributed in the soil. Regardless, there has been an insignificant reduction of pesticides in the soil in the current analysis (Järfälla Kommun et al., 2023). The concentration is highest in the roots and leaves of the plants analyzed, however the report highlights that it is not clear whether the leaves and roots hold the largest amounts of pollutants, as the stems make up the largest amount of biomass (ibid.).

The area was chosen due to its proneness to flooding, and the SVIKT project has successfully hindered flooding and stopped the area from being regularly flooded according to R1 (personal communication, 2023). The ground does not pose threats of flooding and is no longer wet, this due to the added plants and their root systems in the area (ibid.).

The SVIKT project has also contributed with learning possibilities, both for actors involved, but also for other groups, as workshops have been held by the project group. The workshops included students from a school, and representatives of local businesses, with the focus on climate compensation. Avoiding greenwashing and handling the communicative aspects of a project such as the SVIKT project was also discussed in the workshop (Järfälla Kommun et al., 2023). Another way learning has been included in the project is through a Geocache nearby, which is described in the project report (ibid.) to function as an interactive learning-place. The idea is to provide a place where information on the project and its specifics and related topics can be found. Information has also been made available through articles in local newspapers, and through informative signage at the site (Figure 4). Observing the plantation in the beginning of 2024, after the official ending of the project it is obvious that many of the plants have not grown at all (Figure 5), and therefore have not created biomass to bind either CO_2 or pollutants through phytoremediation. The reason for this will be elaborated upon further on.

What happens now that the SVIKT project is officially ended is further explained under 4.1 Scenario 1 - As planned.

Figure 4: Informative sign at the site of the SVIKT project.

Figure 5. Photos from site visit 9 January 2024 showing lack of growth.

2. 3 Lessons learned/main takeaways

The following section will enlist some of the main takeaways and lessons learned, which might be helpful in the event of introducing a similar project in another area. The findings in this section are accumulated through information gathered in the interviews and through the research done during the assessment, such as relevant literature and official documents.

2. 3.1 The importance of site and contextual knowledge

The site was decided upon through a process based on the availability of the land rather than its specifics (Personal communication R2, 2023). The land was and is of no specific use because of repeated flooding, and also happened to be polluted from former activities, which paved the way for the idea of using plants to target different challenges. The pollutants were known to the municipality from previous measurements taken, which was practical as new ones were not needed (ibid.). Other considerations appear overlooked and down prioritized, such as the fact that there were concrete and metal objects all over the area that was priorly unknown of (Järfälla Kommun et al., 2023). An attempt to remove the metal and concrete objects was done, but was considered too time consuming, and the objects were therefore left (ibid.). Another issue that arose was that the soil was only suitable for plantation of salix in spaces where large amounts of water was available. The areas of drought and gravel were proven unsuccessful in growth, and, as mentioned before, did not result in extraction of the toxins or carbon capture, as no new biomass was formed (Figure 5). The issue of varying soil qualities in the area was not examined thoroughly before plantation of the trees, and further knowledge of this could have resulted in even larger amounts of biomass produced (personal communication R1, 2023). The area was also covered in grass and bushes, which is not ideal for salix plantation (Järfälla Kommun et al., 2023).

When planning and performing similar projects it is therefore important to carefully investigate the chosen site, and put emphasis and time on investigating the land area to better adapt the project design to the specific site. As this project was funded as an innovative 2-year project it is understandable that the processes leading up to the start of the project might have been a bit rushed, however, one can learn from this and implement better work leading up to the start of a new similar project.

2. 3. 2 Potential different species

The starting point of the project was to only use salix plants, which is also how the project carried on, and how the plantation looks today. A lesson learned from this approach is that in order to store toxins in the biomass the plants must be able to grow and produce the anticipated amount of biomass. This was not the case for some parts of the plantation area in the SVIKT project (Järfälla Kommun et al., 2023; Personal communication R1, 2023). As previously mentioned, a more careful investigation of the soil conditions and access to water in different parts of the field could have led to a more careful selection of different plants that matched these different conditions. A better match of plants means increased biomass and hence improved toxins removal. However, according to Svenskt Vatten (2019) salix does perform better than most other common greenery in both carbon capture and the extraction of heavy metals, so the choice makes sense, but only for the areas where the trees have actually been growing. Examples of other species with phytoremediation characteristics can be found in the list from Osman (2014) in the appendix.

2. 3. 3 Clear goals and important targets

One of the main takeaways is the importance of clear goals and targets to reach those goals. In this case, R1 and R2 (personal communication, 2023) presented differentiated narratives of the project and the main aim, thus lacking a clear idea of how the proposed goals are going to be met. R2 (personal communication, 2023) explains that it was partly due to the short term funding which limits the abilities to sustain a long term plan to meet the proposed goals. Furthermore, the idea of the pilot was at an first stage to use salix for carbon capture, which came before the site specific challenges. Therefore, the decision to change the SVIKT project aim into a phytoremediation project was made after the municipality's choice of relocating the project to an area with toxins. However the goal of carbon capture remained. Unfortunately the lack of clearance in targets and operations created further difficulties in communicating the project, whereby the two main actors for communication, Barkarby science and the municipality have different roles and regulations on how they can promote a project, which was explained as one of the main challenges by R2 (ibid). There was a hope of increased funding to continue the project, however, the decision was made for the trees to continue growing for an unspecified time while the municipality takes ownership of the care and management of the plantation. If one compares the project description from the municipality to the one that was proposed by the actor Barkarby science, there was significant difference in proposed goals and achievements of the project. This was confirmed, in the interview, as being one considered issue in the project from the municipality´s perspective (Personal communication R2, 2023).

3. Analysis of the results

In this section we analyze the results of the assessment of the SVIKT project, the data and main-takeaways together with the literature review and the knowledge gained throughout the assessment.

A recognized challenge is that there are many functions that clash in this project. For example, as mentioned above, the salix trees in the SVIKT project are supposed to support biodiversity (Personal communication R1, 2023). However, the claim stated in the project report (Järfälla Kommun et al., 2023), that shrubs were kept in order to contribute to biodiversity highlights a conflict in the goals of the project, as the growth of new salix plants would have benefited more from less concurring greenery (Jordbruksverket, 2019). Another example is the implementation of a sandbank, leading to an increase of insects and animals eating their leaves and nectar. However, according to our literature review of phytoremediation, a recognized risk with phytoremediation is the possibility of spreading toxins into ecosystems (McIntyre, 2003). According to McIntyre (2003) there is a significant risk if insects feed on trees accumulated with heavy metals, these metals can be transferred from the plants to the insects. The insects may then become part of the food chain when they are consumed by other organisms, such as birds or predators. This can lead to the transport of heavy metals through the ecosystem. As previously mentioned the project has implemented a sandbank in the area to increase insects and biodiversity, the risk of spreading is thereby necessary to consider.

Another risk is that the leaves can spread to nearby areas and thereby having an uncontrollable spread of heavy metals in the area (McIntyre, 2003; Osman, 2014). This is however at this state only a possible risk and is not as of yet proven in the SVIKT project. As the concentration of pollutants are highest in the leaves and roots of the salix plants, a further investigation of how the leaves are handled when the salix sheds their leaves during fall is well needed. If the leaves are not taken care of the risk of the pollutants becoming degraded to the soil can not be overseen (ibid.).

Another unfortunate clash is the aim of carbon capture while also absorbing toxins in the ground, as the biomass needs to be burned in a sealed off environment, as it releases the carbon captured (see Figure 3). Today, there are few affordable technologies that can separate the heavy metals and toxins from the trees. Therefore, the tree has to be treated as hazardous in certain deployments with the ability to contain the gas filled with the absorbed toxins from spreading. Therefore the materials filled with toxins and heavy metals can not be used in any production because of the risk of the toxins spreading to people using those products (Cudic, 2016).

However, there are current projects which have used thermochemical-based routes: gasification and pyrolysis to be able to create biofuel out of the contaminated trees (European commission, 2021). In that case there is a multifunctional layer of creating biofuel, there is still a question to what extent phytoremediation serves as carbon capture, as it does release the carbon captured. However, according to Hasselgren (2008) salix plantations used for creating biofuels should be credited as a source of carbon capture, due to reducing the need of using fossil fuels to some extent (ibid.). In this regard one can also highlight the emissions that would have been released during a conventional process of getting rid of pollutants in the soil in comparison to using phytoremediation. In this regard phytoremediation can be perceived as a further sustainable option. Mentioned in the project report (Järfälla Kommun et al., 2023), the company Tyréns has made the prediction of phytoremediation having 98% less emissions than using conventional methods for cleaning soil. Carbon capture in the SVIKT project could in other words only be recognized in the following events: In the comparison to other alternatives of getting rid of the pollutants in the soil, or if the biomass binding pollutants can be used in some other way than being burned.

The SVIKT project was proven effective in terms of preventing spreading through water bodies. The large amount of salix trees has been proven to eliminate excess water in the area, reducing the risk of flooding significantly (Järfälla Kommun et al., 2023). The significant biomass has furthermore implications on the local area, such as decreased risk of heatwaves and improved air quality. With a sufficient amount of biomass, which has been planted in the SVIKT project, much points towards the functions of the trees cleaning air pollution, and creating cooling micro climates against heat waves (Han, 2022). The flood mitigation also hinders pollutants from reaching other water bodies with the floodwater that would be present without the SVIKT salix trees. (Järfälla Kommun et al., 2023)

The nutrient cycle is important to consider, as the leakage of nutrients risks causing eutrophication and causing disturbances for microbes. Therefore creating a functioning system underground is important both for the growth of plants and the natural bioremediation process (Wei, 2019). It is also important to highlight the ecosystems of the soil, as cleaning the soil and improving soil quality is central in this project. According to R3, (Personal communication, 2023) microorganisms and microbes are often forgotten in urban plantations. To support a functioning ecosystem for microbes, it is important to have a diversity of plants with longevity. R3 highlighted the risk of short term pilot projects not investing enough time to construct an functioning ecosystem above ground and under (ibid).

Now that the full responsibility for the continuation of the SVIKT project is in the hands of the municipality, there are endless possibilities for the site. Thus, highlighting the opportunities for the municipality to change the trajectory of the project.

4. Alternative future scenarios

Using the analysis of the results and the knowledge gained by the literature review we constructed different future scenarios for the site. The assessment for future scenarios of the current site of the SVIKT project is structured through and based on four scenarios, which will be described and discussed below. The scenarios are then evaluated through a group of targets, which is done with the intent to show what scenarios are expected to perform the best, and in what fields the performance is the highest. Based on the knowledge gathered in the process of this project the scenarios have been tailored to fit the specific area for the SVIKT project, and they are not meant to serve a one size fits all purpose for how to handle similar current or future innovation projects. The scenarios and set targets are presented in Table X, following a coding of green, yellow and red. In this case, yellow signifies unchanged, green signifies improved and red signifies disimproved from current state.

	As planned	Mycorhizza	Let be	Learning env.
Flood risk	Yellow	Green	Green	Yellow
Heat waves	Yellow	Yellow	Green	Yellow
Carbon capture	Red	Green	Yellow	Green
Phytoremediation	Yellow	Green	Green	Yellow
New project	Green	Green	Red	Green
Biodiversity	Yellow	Green	Red	Green
Erosion	Red	Green	Green	Yellow
Preventative: water contamination	Red	Green	Yellow	Green
Plant resilience	Yellow	Green	Yellow	Green
Future possibilities for carbon capture	Green	Green	Red	Green
Education	Yellow	Yellow	Yellow	Green

Worse than current state	Red
Unchanged	Yellow
Better than current state	Green

Table 1. Future scenarios, targets and evaluation of them.

4. 1 Scenario 1 - As planned

In this scenario, one can see in table 1 that there are limited opportunities for carbon capture as the site is planned to become something else in the near future. However, there are therefore new opportunities for carbon capture which can be considered. This alternative will successfully open up opportunities for a new project, while successfully securing erosion, heatwaves and preventing water contamination until the implementation of the new project. However, the phytoremediation process will be stopped at an early stage and therefore there will not be a significant uptake of contaminants in this scenario. Furthermore, biodiversity in this case is yellow, as the municipality is planning on taking care of the salix and therefore prevent leaves from spreading to other areas. However, as it is not possible to guarantee insects from eating the leaves, it is still a considerable threat to ecosystems.

The current plan for the field was just decided by the municipality, and the way forward is to, without a specific set timeframe, let the salix plants grow and continue the process of mitigating floods, remove toxins from the ground and capture carbon. As there is no set time frame the specifics of what happens then are uncertain. However in dialogue with the municipality the direction is the establishment of a park-like area built to mitigate and tolerate heavy rainfall and water masses. This would include the uprooting and removal of the salix plants, which is a given step in the process of phytoremediation (Järfälla Kommun et al., 2023), and then restructuring the area and adding new vegetation and water bodies. The main reason the site will not be exploited in other ways is the flood risk (Personal communication R2, 2023). In practice this scenario builds upon the idea that the salix plants will continue to extract toxins from the ground, and that acceptable levels are reached until the establishment of the area as a rain park or flood mitigator. A suggestion for this scenario would be to look into the project of Kyrkparken in Barkarbystaden, as it is a nearby area which is built to function as a flooding area, with many other potential functions as well, not yet clearly formulated by the municipality.

4. 2 Scenario 2 - Mycorrhiza

Scenario 2 emphasizes mycorrhiza, an ancient fungi that integrates with plants in a partnership, strengthening plant-resilience and functions through establishing a nutrient cycle. In this scenario the salix will incorporate less toxins in their stems and leaves as mycorrhiza will support in breaking the contaminants down. Therefore one can talk about increased opportunities for carbon capture in this case. Furthermore, as mycorrhiza also serves as carbon storage and does not need to be removed and burned off at a facility, the carbon capture will remain. Overall this scenario will increase erosion, prevention of eutrophication and phytoremediation in place due to the functions of mycorrhiza explained below.

In this scenario, there are possibilities for improvements in the growth of the salix, improved soil qualities, increased phytoremediation, and carbon capture. Mycorrhizal can also assess whether plants tolerate drought conditions by improving water uptake and reducing water loss (Rillig, 2006). This could be useful in the project area, as some parts of the area do not hold water well, which has affected the growth of the salix plants. Mycorrhizal fungi can protect plants against root diseases and pathogens, enhancing the plant's overall health. Thus, plants with mycorrhizal associations often exhibit enhanced growth and can therefore be used instead of fertilizers. (Bagyaraj, 2022). Therefore, in the areas with limited growth, mycorrhiza can play a significant role in supporting nutrients and water for the salix, increasing their chances of survival and thereby providing proper phytoremediation. Another point to make is that the soil qualities will be improved significantly by the proteins and glomalin produced in the nutrient cycle imposed by the mycorrhiza. Mycorrhiza fungus's vast root system furthermore helps bind soil particles, preventing erosion and enhancing water retention. Arbuscular mycorrhizal fungi help soil stick together by wrapping their roots around particles (Rillig, 2006). Hence, this scenario both improves the salix health and decreases the risk of erosion.

In comparison to the other scenarios, the networks of the mycorrhiza will stay in the ground and therefore be able to support future plantations and sustain some of the carbon capture in the ground. However, the imposed mycorrhiza will risk disappearing and be aborted by uprooting the salix trees in which they have a synergy. Furthermore, because the project is set on a limited time slot, there are fewer chances for naturally occurring mycorrhiza to develop by itself, therefore this scenario suggests buying mycorrhiza and imposing it in the ground. Ideally, this process would occur naturally, however, in short-term projects fast and effective results are essential, and the limited time period constrains the chances of developing ecosystems in the soil by themselves. Lastly, this scenario supports the idea of being able to impose a new project on the land at an even shorter notice than planned, due to strengthening the functions already in place.

4. 3 Scenario 3 - Let be

In this scenario one can see in table 1 that there are reduced possibilities for new projects as this scenario explores the alternative of letting the plants remain for a very long time. In this case, the phytoremediation process will be significant and the decreased risk of flooding, erosion and heat waves will remain. Furthermore there will be a temporary carbon storage during this process. However, if the municipality would not continue with taking care of the plants, there is a significant risk of the toxins spreading through the leaves into other areas or into ecosystems. Therefore, biodiversity is red in this scenario.

The third scenario explores the idea of, with minimal management, just letting the plants continue to grow, and in that way bind carbon. The scenario is probably the cheapest one, as no new establishments are required. However this scenario might be one of the most questionable in terms of resilience, as it has been stated before the challenges of the toxins becoming part of the ecosystem and the plants classified as hazardous are still present. The scenario would continue to contribute to the mitigation of floods and the hindrance of contaminants reaching water bodies when flooded. To make the scenario a possibility though, measures are needed in order to make sure the spreading of the contaminants in the ground can be hindered, as the scenario otherwise just moves the toxins from the ground into the biomass, which will still be located in the same place, which is unfortunate.

It was mentioned both in the interviews and in the project report (Personal communication R1 and R2, 2023; Järfälla Kommun et al., 2023) that the project aims to increase biodiversity, which could be interpreted as engineering ecosystems and the management of ecosystems, which is an idea closely related to the rewilding discourse. However, while researching rewilding it is apparent that the establishment of ecosystems is a complicated process where ideas and theory often lack in the linkage to the real and situated area (Bocking, 2015). The scenario of letting the plants continue to grow therefore needs more research in order to be able to say if it is sustainable in the long run, as examples of lack of research beforehand has already been highlighted in the report released by the project group. A key example of this is the planned inclusion of beehives in order to increase biodiversity and bring back "lost species" to the area, which is a key concept of rewilding (Carver et al., 2021). It was then realized through expert knowledge that beehives can outconcour wild appearances of bees in the area (Järfälla Kommun et al., 2023).

An idea for the let be scenario could be to investigate the way the plants are growing today, as they are planted tightly, which might not generate the most biomass in the long run, as the plants concur with each other, and might therefore not be able to produce the most possible biomass (Järfälla Kommun et al., 2023).

4. 4 Scenario 4 - Learning environment

In this scenario, one is imposing a new project where a diversity of plants and microorganisms will engage in phytoremediation and other functions, creating a learning environment for others to learn about natural functions. Therefore one can see in table 1, that this scenario secures many of the current reached targets, meanwhile investing in creating a space of different plants and microorganisms. The risk of spreading of leaves will decrease as there will be less deciduous trees in the area. Carbon capture will vary depending on which other plants or fungi will be planted.

The core of this scenario is learning, and understanding ecosystems and natural processes and nature based solutions to problems in an ever changing society. The closeness to two schools is one of the reasons that sparked this idea, as well as the process of assessing the SVIKT project led to many new insights and a broadened knowledge for us. Many of the processes taking place in the project might seem obvious, and as they are not that complicated to understand, the complement of seeing the concepts "in action" for students seems suitable. The learning environment area could contribute with situated knowledge, and inspire young people to learn more about ecology, biodiversity, ecosystems and nature based solutions to current and coming issues due to, for example, climate change. In this scenario, the thinning of salix that has failed to grow will be followed by imposing a larger diversity of plants with the ability to break down contaminants. In other words, the area will become a platform for different nature-based solutions based on the conditions of the space, such as: salix, mycorrhiza, lavender, sunflower, clover, common juniper, Oyster mushroom, meadow sweet ect. The different species will support an increased biodiversity of species with different functions in a long-term project, hence increasing opportunities for naturally occurring ecosystems and microorganisms such as mycorrhiza. The carbon capture goal will then be optimized due to the plants that operate phytodegradation (breaking down pollutants (Osman, 2014). These plantations do not become hazardous waste and therefore do not have to be burned. The plants will have informational signs of each species and their functions for climate-change challenges and people, to teach the kids in the surrounding schools about the importance and diversity of functions of different species. The salix already in place will have the opportunity to grow into larger trees meanwhile, applying a recreational sphere to the project. In this case, one de-prioritizes phytoremediation, in other words, accepts a level of toxins in the ground and instead focuses on knowledge spread, carbon capture, and biodiversity. This idea is based on the assumption that the schoolkids will be safe, due to already acceptable levels of toxins in the ground, limited opportunities to play in the area, and furthermore clear signs of the dangers of consuming in the area.

During the site visit it came to our knowledge that one of the schools in the area has been shut down due to the high levels of ground pollution in the area. The closeness to the schools was one of the main points when developing this scenario. This does challenge the relevance of the scenario, but on the other hand motivates it even more. If using NBS for cleaning polluted grounds is the future one could, on the other hand, argue that the learning environment for such processes is of the utmost relevance in the area today. However, it also highlights the need to ensure that the people enjoying the area will not be posed with risks.

5. Ending Discussion

In this study we have investigated the main steps in implementing the SVIKT project, the main insights from the project and finally, how these insights can be used in the project's continuation. In exploring SVIKT we have also touched upon the SDGs of life below water and life above land, in examining the possible effects on the surrounding ecosystem services and spreading of contaminants when introducing a phytoremediation process. We have found that salix successfully delimits risk of over-fertilization and spreading of contaminants and pesticides through water bodies, however, it has also increased the risk of spreading through the high concentration of contaminants in the leaves. Therefore, this study has highlighted many different challenges with integrating a multifunctional project with a phytoremediation project with deciduous trees, such as salix. As salix serves insects and animals with their toxified leaves, which also can be spread in the wind, there is a need to research to what extent that poses a risk of contamination in ecosystems or spread to nearby areas. However, while it is essential to review risks with caution it is also important to emphasize the importance of phytoremediation as a step in the right direction. SVIKT has undeniably contributed with insights to improve the process, but also highlighted the complexity in using nature based solutions. Thus, there are risks in viewing nature in a technological lens, focusing solely on the specific plant and its functions, but must include the whole ecological surroundings to be able to prevent the spreading of toxins into ecosystems. Hence, routines should be developed to safeguard insects and animals from absorbing the toxins from the plants in phytoremediation and limit the spread from leaves. The SVIKT project is testing new grounds, which evidently will highlight other areas in need of change, in particular the shortcomings of pilot fundings incentivizing short-term projects.

Another important insight is that the SVIKT project is more successful in preventing eutrophication and spreading of contaminants through water bodies then it has been in phytoremediation (as of now at least), meanwhile the project has prevented surrounding households from risks of flooding, erosion and heatwaves. There are therefore many multifunctional benefits of the project, although not the originally intended ones. Therefore it is important to make clear guidelines for similar upcoming projects. In this specific project the whole life-cycle of the trees has not been investigated and remains unclear. Even though the project has claimed to capture CO_2, there is no clear evidence of such, due to the fact that the polluted, harvested/uprooted biomass must be burned and the CO_2 will be released shortly after. However, there are many recognized possibilities in the rhizosphere whereas fungi and other microorganisms can help support the degradation of the contaminants and thus open up the possibility of carbon capture. Regardless, the result of the SVIKT project has revealed the need of continuing to develop routines to enhance the degradation of contaminants or use technologies which can extract and separate carbon and toxins from the trees, to safeguard carbon capture of the plantations. As of now with the current technology and processes available the combination of carbon capture and phytoremediation appears to be clashing, and a complicated setup. This issue is not brought up in the final evaluative report of the SVIKT project. It might look like a good and multifunctional idea at first, but scratching the surface the conflicts between the two become obvious.

However, phytoremediation is an upcoming and interesting operation with immense potential in creating more sustainable alternatives for cleaning soil, meanwhile encompassing the SDGs 11 (sustainable cities), 13 (climate action), 14 (life below water) and 15 (life above land) all at once. Therefore, it is important to assess and improve the processes and routines to ensure phytoremediation can reach its full capacity. The SVIKT project should rightfully be seen as an innovative pilot project contributing with important insights in how one can rethink current operations into further sustainable ones. Although, there are some recommendations we can contribute with to the municipality:

- Secure the risk of spreading by moving the sandbank to a more suitable place and continue with the management of leaves while securing the space from wild animals as much as possible.

- Introduce mycorrhiza, (as it will not be enough time for it to be developed naturally) not only does it effectivize the phytoremediation process, it also contributes with remaining functions of carbon capture, prevention from eutrophication and decreased risk of erosion and flooding regardless of what happens with the salix in the future. Furthermore, some scholars highlight the possibility of enhancing degradation.

- Be more careful with the communication of the project. As there are a lot of complexities within this project we recommend either being on the safe-side and only presenting those functions and successes which can be proven or put in the effort to secure the project reaching the goals of significance for the municipality. Thus, as the project is successful in preventing eutrophication and resilience against climate change challenges in the area, why not celebrate those successes more?

- Keep an opportunistic approach, and take the chance to use the findings of the project and the site itself to help educate future generations and other actors on soil issues, climate change mitigation and other topics touched upon during the SVIKT project.

Recommendations for future similar projects:

- Explore the whole lifecycle analysis, in other words, put effort into securing a sustainable waste management that does not diminish the progress of the project.

- Although salix have many qualifications, using a deciduous tree for phytoremediation does come with challenges of spreading and management of the leaves. Therefore one should incorporate a risk analysis of the site and possibly consider other species when there is critical wildlife and populations nearby. On that note, our recommendation is to use different species as it opens up opportunities to match plants to site specific conditions, and create an ecosystem where the plants can support each other.

6. References

Interviewees:

R. 1 - CEO of the involved companies Clean Nature and Klimatskoga.

R. 2 - Project leader of the SVIKT project and representative of the municipality, chemical expert.

R. 3 - Researcher on soil health and qualities, KTH.

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7. Appendix

7. 1 Interview guide Clean nature

Samtycke och information:

Har vi tillåtelse att spela in intervjun och använda informationen till vår utvärdering av Svikt-projektet?

Projektet SVIKT:

- Hur har processen sett ut? Hur började Svikt-projektet?
- Har ni kunskap kring jordkvalité, vilka föroreningar eller saltnivåer som finns i området?
- Var det någon platsspecifik undersökning innan projektet startade?
- Hur har projektet presterat? Vad är resultaten?
- Vad ligger på erat bord?Till vilken utsträckning är ni fortsatt involverade?
- Upplever du att det finns platsspecifika utmaningar eller finns det universella utmaningar?
- Vilka har varit de andra aktörer som varit med i projektet? Vilken roll och ansvarsområde har de tagit hand om?
- Hur ser planen ut inför framtiden?

Smarta växter:

- Berätta om markrening med Salix
- Vilken typ av salix används och är den naturligt förekommande?
- Vad är normalt tidshorisonten för fytoremediering med salix?
- Vad har varit projektet största framgångar och utmaningar enligt er?

7. 2 Interview guide projektledare och kemikaliesamordnare, Järfälla kommun:

Samtycke och information:

Har vi tillåtelse att spela in intervjun och använda informationen till vår utvärdering av Svikt-projektet?

Projektet SVIKT:

- Hur har processen sett ut?
- Har ni kunskap kring jordkvalité, vilka föroreningar eller saltnivåer som finns i området?
- Var det någon platsspecifik undersökning innan projektet startade?
- Hur har projektet presterat? Vad är resultaten?
- Vad ligger på erat bord?Till vilken utsträckning är ni fortsatt involverade?
- Upplever du att det finns platsspecifika utmaningar eller finns det universella utmaningar?

- Vilka har varit de andra aktörer som varit med i projektet? Vilken roll och ansvarsområde har de tagit hand om?
- Hur ser planen ut inför framtiden?

- Vad för föroreningar finns det i området och hur starkt koncentrera är de?
- Vad har varit projektet största framgångar och utmaningar enligt er?

7. 3 List of potential species for Phytoremediation

The list is taken from Osman (2014) and includes references which are not included in the reference list of this report.

1. Arabidopsis thaliana (Campos et al. 2008)
2. Cucurbita pepo (Trapp and Karlson 2001)
3. Festuca arundinacea (Zand et al. 2010)
4. Galega orientalis (Trapp and Karlson 2001)
5. Glycine Max (Njoku et al. 2009)
6. Hamamelis virginiana (Barnswell 2005)
7. Ipomoea batatas (Doty 2008)
8. Leucaena leucocephala (Doty et al. 2003)
9. Morus rubra L. (Trapp and Karlson 2001)
10. Nicotiana Tabacum L. (Campos et al. 2008)
11. Oryza sativa L. (Kawahigashi et al. 2007)
12. Populus deltoides (Barnswell 2005)
13. Populus spp. (Campos et al. 2008)
14. Quercus spp. (Barnswell 2005)
15. Robinia pseudoacacia (Barnswell 2005)
16. Salix spp. (Campos et al. 2008)
17. Salix viminalis (Trapp and Karlson 2001)
18. Senecio glaucus (Radwan et al. 1995).
19. Solanum tuberosum L. (Inui et al. 2001)
20. Ulmus pumila (Barnswell 2005)
21. Zea mays (Zand et al. 2010)

7. 4 Data of absorbed heavy metals and pesticides

Tabell 3. Analysresultat metaller

KundID Provplats	Blad Prov1	Blad Prov 2	Blad Prov 3	Blad Prov 4	Blad Prov 5
IVL:s provkod	330860	330863	330866	330869	330872
Provtagningsdatum	2023-10-05	2023-10-05	2023-10-05	2023-10-05	2023-10-05
Ankomstdatum	2023-10-09	2023-10-09	2023-10-09	2023-10-09	2023-10-09
Analysdatum	2023-10-25	2023-10-25	2023-10-25	2023-10-25	2023-10-25
Enhet	**ng/g TS**	**ng/g TS**	**ng/g TS**	**ng/g TS**	**ng/g TS**
Arsenik, As	0.14	0.17	0.09	0.042	0.4
Bly, Pb	0.19	0.2	0.22	0.13	0.27
Kadmium, Cd	3.6	5	1.8	0.94	6.4
Kobolt, Co	2.6	1.6	0.62	0.31	0.77
Koppar, Cu	6.3	5.4	3.6	2.9	5.8
Krom, Cr	0.36	0.31	0.40	0.22	0.34
Mangan, Mn	550	780	86	110	430
Nickel, Ni	2.2	1.6	2.4	0.89	1.5
Vanadin, V	0.22	0.23	0.29	0.16	0.21
Zink, Zn	340	700	290	220	860
*Barium, Ba**	*4.0*	*15*	*7.0*	*5.0*	*17*
Molybden, Mo	1.4	1.2	0.84	0.19	2.0
*Strontium, Sr**	*49*	*60*	*24*	*12*	*41*
*Antimon, Sb**	*0.073*	*0.06*	*0.069*	*0.052*	*0.073*
Kvicksilver, Hg	46	31	24	16	17
%TS	34	42	42	44	40

**IVL har inte ackreditering för denna analyt.*

Salix leaves absorption of heavy metals (Cleannature 2023).

Tabell 2. Forts. Analysresultat PCB, HCB och klorerade pesticider

KundID Provplats	Rot Prov1	Rot Prov 2	Rot Prov 3	Rot Prov 4	
IVL:s provkod	331296	331297	331298	331299	
Provtagningsdatum	2023-10-05	2023-10-05	2023-10-05	2023-10-05	
Ankomstdatum	2023-10-09	2023-10-09	2023-10-09	2023-10-09	
Analysdatum	2023-10-25	2023-10-25	2023-10-25	2023-10-25	
Enhet	**ng/g TS**	**ng/g TS**	**ng/g TS**	**ng/g TS**	
*Hexaklorbensen (HCB)**	*1.7*	*18*	*17*	*29*	
PCB 28	<0.13	<0.17	<0.20	<0.18	
PCB 52	<0.13	<0.17	<0.20	<0.18	
PCB 101	<0.13	0.45	1.0	0.18	
PCB 118	<0.094	0.52	0.67	<0.14	
PCB 153	<0.094	0.65	2.2	0.33	
PCB 138	<0.094	0.73	2.8	0.31	
PCB180	<0.094	0.25	1.4	<0.14	
Summa analyserad PCB7	**0**	**2.6**	**8.1**	**0.82**	
*pp-DDE**	*0.57*	*5.3*	*20*	*17*	
*pp-DDT**	*0.13*	*0.39*	*1.4*	*0.55*	
*pp-DDD**	*0.33*	*1.3*	*15*	*10*	
S:a klorerade pesticider	1.0	7.1	36	27	
%TS	69	55	55	48	

**IVL har inte ackreditering för denna analyt.*
Rot Prov 5 saknas, ej tillräckligt med prov inskickat från kund för att genomföra samtliga analyser.

Salix root absorption of pesticides (Cleannature 2023).