Supporting Wild Bees on Green Roofs and Green Walls

– conscious plant selection and overseeing the municipalities work

Främjandet av vildbin på gröna tak- och väggar – ett medvetet växtval och kommunernas arbete

Kittima Ritthichot

Självständigt arbete • 15 hp
Sveriges lantbruksuniversitet, SLU
Fakulten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap
Landskapsarkitektprogrammet
Alnarp 2022

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Omfattning:	15 hp
Nivå och fördjupning:	G2E
Kurstitel:	Självständigt arbete i landskapsarkitektur
Kurskod:	EX0845
Program/utbildning:	Landskapsarkitektprogrammet
Kursansvarig inst.:	Institutionen för landskapsarkitektur, planering och förvaltning
Utgivningsort:	Alnarp
Utgivningsår:	2022
Omslagsbild:	Kittima Ritthichot

Nyckelord: Wild bees, Urban pollinators, Green roofs, Green living walls, Plants for pollinators

Sveriges lantbruksuniversitet

Fakulten för landskapsarkitektur, trädgårds- och växtproduktionsvetenskap

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Abstract

The importance of pollinators in urban areas have become a topic of current interest with increasing urbanisation. The current trend of urbanisation, e.g., tall buildings, concrete and densification, has forced green structures to adapt to the changes, resulting in biodiversity loss. As urbanisation continues, cities will continue to expand and thereby, it is crucial to halt the loss of biodiversity. A solution to tackle the limited space has been the implementation of green roofs and green walls. With the promising opportunities that emerged with the development of green roofs and living walls, this study aimed to investigate how the habitat requirements of wild bees could improve on these constructions. The study conducted a literature review about wild bees and projects focusing on wild bees from municipalities in Sweden. Additionally, lists (Tab. 1-6) of attractive plants to wild bees were created to improve habitat requirements.

The study results indicate that preserving wild bees requires an interdisciplinary approach as multiple factors should be considered. Although the literature review results have shown that green roofs can effectively support biodiversity, uncertainties of the effectiveness of supporting biodiversity remain on green walls. The compiled lists of plants suitable for semi-extensive green roofs and wild bees is based on literature and all plants have not been tested in practice; therefore, it should be used as a guideline to reference/experiment. The study results also showed successful biodiversity preservation projects from municipalities, indicating that the cooperation and incentives from planners, the public and municipalities are valuable to halt the loss.

Green roofs and green living walls are merely a complement to further enhance the existing green structures for wild bees. Urban areas are merely one of the habitats for wild bees and cannot replace their natural habitats.

Preface

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Introduction

The global decline of biodiversity has been associated with climate change's impact over the past decades (IPBES 2016; IPBES 2019). There are numerous factors behind the decline of biodiversity of pollinators. However, the alarming numbers of threatened and endangered species have made the public more aware of the importance of pollinators as it correlates with crop production (IPBES 2016; Naturvårdsverket 2018; Tunón & Sandell 2021). Crops and flowers are dependent on animal pollination to some extent. Changes in pollinating species would, e.g., affect the global crop production, food supply and recourses for species. Therefore, pollinators are crucial and beneficial for agriculture, society and nature (IPBES 2016; Tunón & Sandell 2021).

Most of the pollinators in Sweden are insects, i.e., wild bees, honeybees, butterflies, hoverflies and flies. Numerous studies have shown that the decline of pollinators in Sweden is associated with multiple factors – e.g., land-use changes, increased urbanisation, and modern agricultural methods (IPBES 2016; Naturvårdsverket 2018; IPBES 2019). Whilst the studies may be few, indications of the national decline of wild bees have been found. In recent years municipalities and public organisations have been working to allieviate the loss of wildbees in Sweden (Naturvårdsverket 2018; Naturvårdsverket n.d.b; Naturvårdsverket n.d.c). The habitat requirements need additional improvement in the preservation of pollinators. (IPBES 2016; Naturvårdsverket 2018).

Although the importance of pollination as an ecosystem service has been introduced and emphasised by many researchers, urbanisation continues to contribute to the decline of biodiversity (CBD 2012; IPBES 2016). Pollination is an ecosystem service that provides a vital life-support function; therefore, changes in pollinators will affect our life-support system. The pollinators that contribute the most to pollination in Sweden are wild bees and honeybees (Naturvårdsverket 2018). Reports have also indicated the local decline of wild bees (IPBES 2016; Naturvårdsverket 2018). According to Artdatabanken (2020), 231 of nearly 300 wild bees in Sweden can occur in urban environments, 34 are threatened, and 2 are extinct.

A vast majority of the affected species reside in an urban environment. The cities are diverse and feature different types of landscapes, therefore, creating unique habitats (Lentini et al. 2016). Urban areas have been undervalued as a place for biodiversity and could potentially create favourable environments for wild pollinators to meet their habitat requirements (Twerd & Banaszak-Cibicka 2019). The concept of green roofs and green living walls has improved significantly over the past years with recent development. The questions, namely whether green walls can support preserving and enhancing the abundance of wild bees in urban areas, remain ambiguous (Madre et al. 2013; Manso & Castro-Gomes 2014; Mayrand & Clergeau 2018). As urbanisation continues, cities will continue to expand. There is, therefore, the potential to utilise green roofs and green walls to support the biodiversity in urban areas.

A further enhancement to support biodiversity would be to increase the overall biodiversity of flowering species. The study indicates that adequate patch sizes, diversity of plant species and conscious plant selection were important (Andersson 2017; Haaland 2017; Mayrand & Clergeau 2018; Naturvårdsverket 2018). Subsequently, the study focused on finding and assembling a list of highly attractive species to support one of the wild bees' habitat requirements.

With the preservation of biodiversity in consideration, less maintenance on green structures would improve the overall biodiversity. However, some challenges have occurred when implementing green structures to preserve biodiversity, e.g., the absence of maintenance knowledge and an understanding of pollinators' preferences (Persson 2012; Naturvårdsverket 2018; Tunón & Sandell 2021).

The Swedish Environmental Protection Agency (*Naturvårdsverket*) finances the municipalities and non-profit organisations through *The Local Nature Conservation* programme (LONA) to preserve biodiversity. Municipalities are therefore responsible for developing these projects; however, local authorities can also be involved or initiate projects. (Naturvårdsverket n.d.a). Although many roofs and walls are private, it is essential to know how municipalities work to preserve the biodiversity of wild bees, especially on green roofs and green walls as, they have the potential to enhance biodiversity. Municipalities have an advantage in starting projects and spreading information to the public. Municipalities could utilise their communication network to inspire the public to learn more about wild bees or engage the public in preserving biodiversity/pollinators/wild bees.

1.1. Aims

The study aims to investigate why the diversity of wild bees should be preserved in urban areas. Additionally, the aim is to study which type of plant species could benefit wild bees on green roofs and green walls. Finally, the aim is to study how municipalities work with wild bees on green roofs and green walls.

1.2. Purpose

The purpose of this thesis is to emphasise the importance of wild bees in urban areas. The purpose is to create a concise article with information about the potential to aid the preservation of wild bees on green roofs and living walls in an urban planning context.

1.3. Research questions:

- Why do we need to preserve wild bees in urban areas?
- What plant species can be used to benefit wild bees on green roofs and green walls?
- How have the Swedish municipalities been working with preservation of wild bees in urban areas?

1.4. Materials and methods

1.4.1. Literature study

The first part of the thesis will be a literature study and the search for scientific articles will be conducted by primarily using SLU's search engine Primo, Google Scholar and ScienceDirect. Other articles written by relevant sources such as reports from The Swedish Environmental Protection Agency, regions and municipalities will also be used. Information about green roofs will mainly be taken from Grönatakhandboken (2021) as the constructions should be perceived through a Swedish perspective of green roofs.

The book *Biologisk mångfald, naturnyttor och ekosystemtjänster* have been used to learn and understand the current situation of biodiversity in Sweden. *Gardening for bumblebees* has been used to gain learn about bumblebees, pollinators and contributed plants to the list.

1.4.2. The plant list

The second part of the study will be assembling lists (Tab. 1-6) of attractive plant species on green roofs and green walls for wild bees. The sources have been deemed trustworthy before the usage.

The initial start of the plant lists (Tab. 1-6) was to find suitable plants for green roofs with similar biotopes, e.g., dry and mesic meadows by using Dunett & Kingsbury (2004), Paju (2015) and Wahlsteen (2018). Hammond (2016) and Mossberg & Stenberg (2018) was used to find information about native plants along with SLU's Swedish Species Information Centre (Artdatabanken). The plants that work on green roofs and green walls might not be attractive to pollinators. Subseqently, the pursuit led to finding verifications through reports and documents; from, e.g., Naturskyddsföreningen (n.d.), Pollinera Sverige (n.d.) and Persson (2012). The Royal Horticultural Society (RHS)'s website was also used to search for verifications, hadiness zones and flowering seasons. The interviews contributed with some species to the list, the bulb professional's answers in the questionnaire contributed significantly to the understanding of bulbs in urban areas and bulbs on the list. The plants and bulbs recommended by the professional also went through verication of being pollinator-friendly through the previously mentioned sources. Additionally, websites of nurseries and plants have been used to reference the plants' hardiness zones and flowering seasons. Observations of existing green roof and green wall constructions in Malmö, Sweden, have also contributed to the plant list.

1.4.3. Interviews

Interviews were conducted by talking with three professionals who work with green roofs, green walls and bulbs. The interviews intended to perceive green roofs and green living walls in Sweden through a professional's perspective. Practical knowledge differs depending on the geographical zones, and the selected professionals have worked in locations in Sweden and gained knowledge that could not be found in scientific articles.

- The interview with the green roof/wall professional was performed at Klinta Garden, lasting between 30 – 45 minutes, where mainly green roofs were discussed while looking at experiments of green roofs and green walls (Korn 2022).

- The interview with the green living wall professional was a phone interview where some questions were prepared, the answers lead to further discussion lasting between 45 – 60 minutes (Öqvist 2022).

- The interviews concerning bulbs were answered through a prepared questionnaire document (Wembling 2022).

The keywords were primarily in English, except for some Swedish ones related to pollinators in Sweden. The keywords preserving biodiversity include: preservation of biodiversity, loss of biodiversity in urban areas, pollinators in urban areas, wild bees in urban areas, Pollinatörer i Sverige and more.

The keywords used for green roofs and green living walls include: green roofs, green walls, living walls, biotope green roofs, semi-intensive green roofs, intensive green roofs, abundance on green walls and more.

1.5. Demarcation

The pollinators that will be discussed are wild bees, i.e., bumblebees and solitary bees, as the diversity is deemed important (Persson 2012; IPBES 2016; Naturvårdsverket 2018). Many of these species commonly exist throughout Sweden.

The plants suggested will be primarily those that can grow in the southern part of Sweden. However, most of them can also be used in other parts of the country. To narrow down the study, it will only be focused on urban areas in the south of Sweden with plant hardiness zones between 1 and 4.

The majority of the wild bees in Sweden are not active after mid-august; therefore, the focus will not be on late-flowering species. The purpose of the plant list is to be used as a reference for experiments or as a guideline to find suitable plants for different conditions, primarily in urban planning and landscape design on green roofs and green living walls. Difficulties were found in the search for plants species that thrive on green living walls. However, the study found evidence that vegetation on the green roof would generally work on green living walls (Dunnet & Kingsbury 2004). Therefore, the lists' premise is that are plants suitable for semi-intensive roofs will work on living walls. The list was conducted in the interest of finding information about pollinator-friendly plants. Therefore, the suggested plants are mainly native species, as they are more attractive to wild bees. Diversity of flowering species is also important; hence, exotic plants will also be suggested (Persson 2012; Naturvårdsverket 2018; Goulson 2021).

The vegetation beds on green roofs and green walls are constructed differently from traditional flowerbeds and have different microclimates. The discussion about different construction methods is limited to a general introduction when discussing

the ability of plants to thrive in differing conditions. There are many different types of green roofs. However, the study will only cover semi-intensive and biotope roofs as they have been deemed to efficiently support the preservation of biodiversity. The thesis shall only cover green living walls as these are relatively new and uncharted in comparison to other subcategories of green walls. The potential of these seems to enable possibilities to enhance the preservation of pollinators' biodiversity further. The concept of green walls is relatively “new”. The absence of practical experience and studies of plant species has been a challenge in assembling the plant list; therefore, there will not be a separate list for plants on living walls, and the primary focus will be on plants that thrive on green roofs. The demarcation has been made with consideration of the timespan of the study.

Municipalities in Sweden have a scale to measure the amount of green space in urban areas, namely Grönytefaktorn (GYF), where different types of green structures have different points. The GYF-system is complex and differs to municipalities; therefore, the discussion shall be limited to the interview as one professional mentioned this.

Although the focus of habitat requirements will be on foraging – i.e., flowering species, it is important to know that forage on its own, will not solve the loss of wild bees. Other factors, e.g., nesting place, pesticides, protection from wind and adequate sun exposure would also be important.

2. Outlook on biodiversity

2.1.1. The current situation of pollinator biodiversity

The extreme change in the climate is one of the main drivers leading species towards a sixth mass extinction of species within the next 50 – 100 years (Dunn et al. 2006). IPBES global assessment report in 2019 suggests that nearly 1 million species are facing extinction. Although it is common for the number of species to decline, the rate of their decline is estimated to be 10-1000 times faster than the previous rate (Ceballos et at. 2015; De vos, J.M. et al. 2014). IPBES (2016) also highlights the significance of the consequences of the decline of pollinators; 90% of the wild flowering plant species are dependent on pollination globally. Animal pollination is also responsible for 35% of the global crop production, e.g., coffee and almonds; accordingly, employment and income of many groups is thus reliant on animal pollination. As such, pollination provides an extensive resource for other species and are a crucial part of the ecosystem (ibid).

The demands of urbanisation have extensively exploited natural resources. The exploitation seems to occur in biodiversity-rich areas, endangering biodiversity protection and management of ecosystem services (CBD 2012). According to CBD (2012), the population in urban areas will double by 2050. Therefore, the exponential growth of urban areas exacerbates the increased implementation of new green space coverage in Europe (Fuller & Gaston 2009).

Changes in the ecosystem coerce the adaptive responses on the ranges, abundance and seasonal activities on some wild pollinations (IPBES 2016). Consequently, there is a high possibility for the northern wild bee species in Sweden to disappear as they will be forced to the northern extremity (Naturvårdsverket 2018). Despite the absence of studies on the national population decrease of wild pollinators, some indicators have shown that the species have decreased their geographical dispersal nationally and become threatened (Naturvårdsverket 2018; Artdatabanken 2020). While the ecosystem can adapt to changes, there is a substantial gap of knowledge in the quantity of loss the ecosystem can maintain and the types of species that the ecosystem can sustain itself without (Túnon & Sandell 2021). A disruption in the ecosystem could lead to many uncertainties and is therefore not sustainable.

According to Persson (2012), resilient and sustainable urban living needs a "buffer". It is vital to utilise urban areas to create a habitat for the wild bees to seek refuge if their habitat requirements cannot be provided in their current habitat. The ecosystem is experiencing continuous changes due to climate changes; therefore, a "buffer" is needed to preserve diversity within wild bees (Persson 2012; Tunón & Sandell, 2021).

2.1.2. Main drivers of the decline of wild pollinators in Sweden

Figure 1: "Lupines, Invasive Species" (2020)

According to *Naturvårdsverket* (2016), most of the pollinators in Sweden are insects, and it is evident that their habitat requirements are inadequate as species still are threatened. The main drivers generating the decline of wild pollinators are land-use conversion, intensive agricultural practices, invasive alien species, climate change, pesticides, environmental pollution, pathogens, overgrowth of habitats (IPBES 2016; Naturvårdsverket 2018; Goulson 2021). The most significant concern in Sweden is land-use conversion, resulting in the loss of key habitats for pollinators, such as hay meadows, open grass fields and pastures (IPBES 2016; Naturvårdsverket 2018). In addition, the removal of ditches and field margins also affects the habitats. The key habitats for pollinators have become fragmentated and isolated (Brommarco et al. 2012; Naturvårdsverket 2018). A recent study of the vegetation composition in the southmost part of Sweden has indicated the composition changes over the last 200 years. The same study indicated that, despite the limitations of data, the compositions of the flora has changed and become more homogenous, thus, suggesting a loss of biodiversity of both flora and fauna on a regional scale (Hallman et al. 2022).

It is essential to halt the loss of pollinators; the geographical distribution of pollinating species will be affected, although it will not be prominent until a few decades later (Naturvårdsverket 2018). An interdisciplinary approach needs to be established to alleviate the loss. Providing nest sites and resources, protected areas for wind, adequate sun exposure, could improve their habitats. The flowering species should be chosen strategically, i.e., continuous flowering, during the active periods of the wild bees. Pesticides should be avoided as they are harmful and affect

the working bees and the larvae (Persson 2012; Berghauser Pont et al. 2017; Goulson 2021).

Figure 2: "Monoculture" (2020)

2.1.3. Honeybees as a replacement for wild bees

Commercially bred honeybees could replace the wild bees with beekeeping as a hobby. However, long-term dependency on one species is inadvisable. It does not support the preservation of biodiversity, nor is the pollination consistent. Firstly, honeybees are prone to diseases, e.g., Varroa mite, American foulbrood, viruses, fungi, parasites and bacteria. Allegedly, long-distance transportation and dividing colonies increase the risk of transmissions of diseases (Stokstad 2007; Persson 2012). During 2006-2007 U.S beekeepers were significantly affected by the *Colony Collapse Disorder* (CCD), a disorder that afflicts honeybees, characterised by an abrupt loss of bees, resulting in nearly empty beehives. About 50% reported inconsistent symptoms in their colonies; although it has since declined, it remains of concern (EPA 2021).

Secondly, dependency on one species makes the pollination in the ecosystem prone to interannual variation. Interannual variation in pollination could affect the liability of pollination in crop production and wild plants. With interannual pollination, the yield from crops would be inconsistent and unreliable. It would affect millions of people if the food supply were inadequate or if their employment was terminated, owing to uncertainties in pollination (Brommarco et al. 2012; IPBES 2016).

Finally, IPBES (2016) suggests that the decline in pollinators on a local scale showed a decline in crop production. A study of red clover yields in Sweden shows the correlation between unevenness in the community composition of pollinators,

reduced stability, and the crop production level. According to Brommarco et al. (2012), crop production will become more stable with diversity with service-delivering pollinators. Although many indicators have shown that wild bees are decreasing in Sweden, there is a substantial gap of knowledge of how the potential competition and disease transmission from honeybees might affect populations of wild bees (Naturvårdsverket 2018). However, other studies suggest that big colonies of honeybees, co-existing with wild bees, proposes a risk for short-tongued wild bees, as honeybees generally have short tongues. The studies also indicate that the forage competition increased when the floral resources were scarce (Goulson & Sparrow 209; Thomson 2006).

2.1.4. Wild bees in urban areas

In the southern part of Sweden, urban areas can be a valuable habitat to 231 wild bees; 34 of threatened and 2 are extinct (Artdatabanken, 2020). According to a report by *Naturvårdsverket* in 2018, the second most valuable landscape type for threatened bees was urban areas. Therefore, preserving wild pollinators in urban areas should be considered for future development (Arhné 2008). According to Berghauser Pont et al. (2017), to compensate with 30 ha of the increased density, 100 ha of green structures should be implemented to preserve the current level of biodiversity; i.e., half of the roofs on the new buildings would convert to green roofs.

Linking habitat patches could also potentially enhance the pollination of wild plants (IPBES 2016). The contribution to urban biodiversity will be enhanced with the coverage of vegetation on buildings when applied to a substantial extent; it will equally affect other human-induced changes, e.g., temperature reduction, stormwater management and air quality (Manso, M. & Castro-Gomes). Multifunctional solutions should be prioritised and improved as the cities become denser to preserve and fulfil other urban needs (Andersson 2017).

3. Green roofs and green walls

3.1.1. Abundance of wild bees on green roofs and green walls

Solitary bees are generally short-distance flyers when searching forage; thus, the nest (artificial and natural) should be within the range of 150-600m from the forage (Persson 2012). In search of forage, the short-distances flyers tend to be more sensitive to the distance between their habitats (Berghauser Pont et al. 2017). Although green walls and green roofs have shown demonstration to support biodiversity, the variety of patch sizes of green spaces, distance to green spaces, and the buildings' height negatively affect animal and plant populations in cities. Therefore the unification of green structures and patches throughout the city would create a coherency of green structure (Parkins et al. 2015; Berghauser Pont et al. 2017; Matthies et al. 2017; Mayrand & Clergeau 2018).

Green spaces in urban areas are often fragmented and isolated; thus, green walls could potentially act as a junction between the fragmented and isolated green roofs. Biodiversity on green roofs and green walls are dependent on numerous factors. Nonetheless, with the sparse collection of data indicating whether height affects biodiversity on green walls, it is difficult to determine the effectiveness to support the species (Mayrand & Clergeau 2018). However, the potential of green wall systems is continuously developing and improving to perform better and more efficient with the ongoing studies. It could potentially have a more significant coverage than green roofs as there are more facades than roofs (Manso & Castro-Gomes 2014; Mayrand & Clergeau 2018).

The wild bees can reach the roof on the fifth floor, searching for a nesting place. Likewise, they could continue searching for forage on higher ground from their nesting (Andersson 2017). However, green roofs isolation on taller buildings remains an issue (Mayrand & Clergeau 2018). According to Mayrand & Clergeau (2018), the ability to reduce the isolation to green roofs by using green walls as a "steppingstone" remained questionable. Additionally, the exchange between green roofs and habitats outside the cities will also affect bees despite being mobile species (Mayrand & Clergeau 2018). According to Goulson & Stout (2001),

bumblebees had difficulties finding their way home when transported to an unfamiliar location.

Figure 3:"Augustenborg's Roof Garden" (Lin 2021)

According to Parkins & Clark (2015), green roofs are of high value in high-density areas such as New York City, where the amount of rooftop space more than doubles the areas of green space. Urban green roofs have also indicated more bat activity for several North American species than conventional roofs (ibid). In another study, Partridge & Clark (2018) found a higher abundance on green roofs than conventional roofs on migrating and breeding birds. Another study in Staffordshire, UK, found nesting and abundance of birds on living walls compared to conventional bare walls (Chiquet et al. 2012).

3.1.2. Some challenges for green roofs and green living walls

Green roofs development has progressed significantly over the past few years. However, there are still challenges for the implementations that affect green roofs and green walls. According to Andersson & Karlsson (2014), the main challenges to implementing green living walls in Sweden generally are the absence of experience and knowledge among the public and potential customers delaying living walls' development. The maintenance of green roofs and green living walls also impedes the development of both. The public and other authorities have diverse perceptions of how these systems should be maintained. Additionally, the absence of good examples that could enhance the argument also adds to the uncertainties of adopting the technique (Andersson & Karlsson 2014; Mayrand & Clergeau 2018).

The maintenance of the green roofs and green living wall system is low compared to conventional parks. However, it is crucial to be aware that green roofs and green walls are not maintenance-free (Andersson & Karlsson 2014; Mayrand & Clergeau 2018; SMHI 2019; Grönatakhandboken 2021). Green roofs and green living walls will require maintenance at least once a year, some supervision to establish vegetation and additional maintenance if the design has specific requirements (Andersson & Karlsson 2014; Grönatakhandboken 2021). The maintenance approach differs depending on the type of system and the desired appearance (Grönatakhandboken 2021). However, it should be acknowledged that a "wild" composition of vegetation is generally preference by wild bees and comes with the additional benefit of requiring less maintenance. Less maintenance would also improve the overall biodiversity of species as the vegetation is allowed to grow taller. "Wild" grown plants could be utilised as a nesting place for some species as they prefer to nest within cavities or shrubs of plants (Persson 2012; Naturvårdsverket 2018).

Figure 4: "Living wall at a car park in Malmö" (2021)

Figure 5:" Wild flowerbed" (2021)

The appearance of green roofs and green living walls in different seasons also seem to be a constraint (Dunnet & Kingsbury 2004; Andersson & Karlsson 2014). The green structures were initially created to improve the environment for humans and induce recreational activities in cities. With the continuous changes in the world, the purpose of green structures has developed (McCleery et al. 2014). Prior interest in greenery's "wild" and disorientated characteristics have changed to a more modern and structured design over the past decades (Dunnett & Kingsbury 2004). The purpose of green structures does not have to be decorative. The benefits and functionality of greenery to pollinators in the cities could, e.g., be representative, induce knowledge about biodiversity naturally or attract passersby (Tunón & Sandell, 2021).

3.2. The constructions

3.2.1. Green roofs

Green roofs can generally be categorised as *extensive*, *semi-intensive* and *intensive*, depending on the level of maintenance and design (Grönatakhandboken 2021).
Extensive roofs are low maintenance with 30-150mm depth and will retain 50-250 kilos of water/m^2. Semi-intensive roofs are medium maintenance with 120-350mm depth and will retain 150-500 kilos of water/m^2. Intensive roofs are high maintenance with 300-600mm depth and will retain hundreds to tons of water/ m^2 (SMHI 2019; Grönatakhandboken 2021).

Figure 6: "Rockery Inspired Green Roof" (2021)

Semi-intensive and biotope roofs are not different types of green roofs. Biotope roofs can be semi-intensive as semi-intensive only refers to the maintenance level and design of the green roofs. Likewise, a semi-intensive roof does not have to be a biotope roof; it is possible to construct different meadows on semi-intensive roofs.

Figure 7: "Green Roof Experiment" (2021)

Figure 8: "Drought Resistant Plants on Green Roof" (2021)

Biotope roofs are green roofs that are based on a specific biotope's plant composition and characteristics. Meadows, brownfields and heaths could be used as a reference biotope (Grönatakhandboken 2021). This system is recommended if the aim is to enhance the biodiversity, particularly if native species are used. The reference biotope should be a local i.e., similar in hardiness zones of the plants, to enhance the preservation of local species. The roofs should have a minimum depth of 100mm; though the recommendation is 150mm depth to enhance the resilience and sturdiness of the plants used (ibid). According to Grönatakhandboken (2021), biotope roofs with a depth of 100mm or less have not shown good development of a meadow biotope roof.

The significance of high diversity in these systems truly excels as it enhances the resilience of the system. A high biodiversity includes a minimum of 50 plant species with different strategies to flowering, growth and adaptability (Andersson 2017). The ability to sustain and maintain an implemented biotope depends on the system's ability to adapt to the environment that it is implemented in. Therefore, the understanding of the abiotic and biotic factors of the location is important to sustain and maintain the biotope (Andersson 2017; Grönatakhandboken 2021).

Figure 9: "Semi-intesive Roof Garden in Augustenborg" (2021)

Figure 10: "Underlating Roof Landscape" (Wahlgren 2021)

Invasive plants should also be taken into consideration when implementing green roofs as they could disperse into the local environment. *Naturvårdsverket* has an updated list on invasive plants in Sweden that should be checked before implementation of any plants into the systems (Grönatakhandboken 2021).

3.2.2. Green living walls

Green walls are a vertical greening system based on a growing substrate without contacting the ground (Köhler 2008; Mårtensson et al. 2014). The categorisation of walls can generally be divided into green facades and living walls. These two categories can be expanded into several more subcategories. Green façades walls utilise the plant's climbing or hanging ability to grow vertically while living walls are more developed. There are two types of green living walls: continuous and modular systems (Manso & Castro-Gomes 2014). The continuous green walls consist of lightweight and permeable screens where plants are inserted individually. Modular green walls have a specific dimension with growing media where the structure is supported by complementary configurations, e.g., trays, vessels, planter tiles or flexible bags. The complementary configurations are implemented on a panel, which can be implemented directly on vertical surfaces. The green living wall system also requires irrigation to provide water; there are different types depending on the type of green living wall (ibid).

Figure 11:" Green Living Wall with Flexible Bags at Mobilia" (2021)

Figure 12: "Plant on Stone Wall" (2021)

According to Dunnet and Kingsbury (2004), the plants suitable for the living walls are lower, creeping and trailing plants. The plants for living walls can be found on old walls and the same environments as the green roofs. However, green living walls can host a greater variety of plants than green roofs. If the green living walls are implemented on a lower height profile, it is possible to host plants that require more moisture and shade (Dunnet & Kingsbury 2004). It is challenging to determine the plants for green living walls due to the varying conditions on green living walls, e.g., the different latitude, irrigation system, climatic conditions and shade (Manso & Castro-Gomes 2014).

3.2.3. Interviews with professionals working in Sweden

Interview with a living wall professional

During an interview with a professional working with green living walls in Sweden, the professional thought the lack of examples of aged green living walls, implementation cost, dampness, experience, knowledge and appearance during the winter were the main issues when promoting the concept to potential customers. Despite that, the green living wall professional explained that the interest and understanding were there once they explained the system and benefits to the potential customers. The green living wall professional explained that customers would request beautiful greenery of lush walls more significant part of the year, attractive to pollinators and contribute to GYF. In another interview, a green roof/wall professional had their own nursery; thus, the access to plants was extensive.

Interview with a green roof/wall professional

In an interview with a green roof/wall professional, they explained the importance of good drainage on green roofs they have worked on. The professional emphasised that a good drainage system would not allow weeds to become as invasive. Creating an undulating landscape with natural or artificial resources generates heat that benefits both the plants and pollinators. The professional explained that the plants should struggle during the first year of the establishment to promote seed and root dispersal. The plants would become more resilient to the changing climates by establishing a robust rooting system. Furthermore, the professional suggests that annuals, biennials and bulbs should be added to temporarily create the green roof's desired appearance.

Figure 13: "Living Wall Experiment at Klinta Garden I" (2022)

Figure 14: "Living Wall Experiment at Klinta Garden II" (2022)

4. Attractive plants for wild bees and where to find them

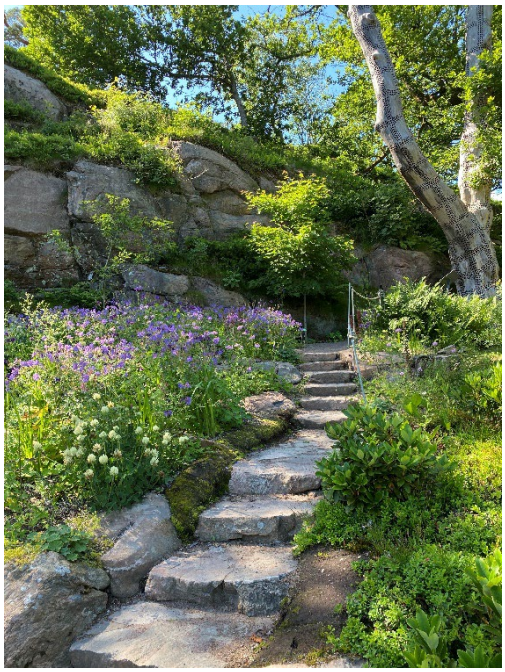

Figure 15: Plants on Rockery I (2021)

Figure: 16: Plants on Rockery II (2021)

4.1.1. Hardiness and reference places

The conditions on green roofs and green living walls vary considerably; therefore, it is essential to understand the microclimate on the location. The types of plants used here should have a resilience towards drought and low-nutrient conditions. It is also important to remember that perennials need to establish their root system before flowering. Hence, adding annuals or biennials is a good solution for flowering in

Figure 17: Exposed and dry herb garden (2020)

the early stages of establishing the plantation beds. Microclimates, hardiness zone, latitude, incline and abiotic factors of the location should be taken into consideration before applying the usage of the plants (Grönatakhandboken 2021; Mårtensson et al. 2014; Paju 2015).

Reference places for the plants can be found in similar characteristics of dry, low-nutrients, limited water and sun/wind-exposed environments. The landscape types are akin to the described environments: steppes, prairies, rockeries and meadows; in Sweden, similar environments are found in different meadows on Gotland and Öland. Likewise, it can be found on brownfields, coastal meadows and heaths (Paju 2015; Wahlsteen 2018; Grönatakhandboken 2021).

Figure 18:"Gotland's coast", (Henriksson 2021)

Figure 19:"Gotland's Nature" (Henriksson 2021)

4.1.2. Native, exotic or cultivated plants?

The types of plants that would benefit wild bees in Sweden the most would be local wild species as some of these species are host plants for pollinators (Naturvårdsverket 2018). Previous results indicate that the change of land-use has dramatically affected the wild flora of the key habitats for pollinators, causing foraging competition for the pollinators (IPBES 2012; Bucharova et al. 2017 Naturvårdsverket 2018; Goulson 2021; Hallman et al. 2022). Thereby, implementing local wild species would improve the habitat requirements for wild bees. According to Naturvårdsverket (2018), new species have been introduced and restored with

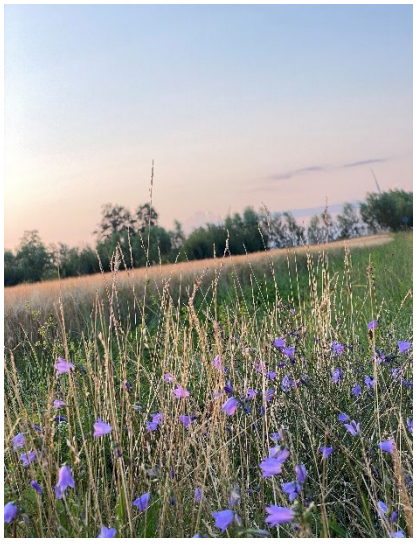

Figure 20: "Bluebells" (2021)

the implementation of local wildflowers. A study of local and exotic plants conducted in Germany also showed that the local plants performed remarkedly better than exotic plants. The same study did, however, acknowledge that the results of local adaption studies may be uncertain due to the different approaches these studies took (Bucharova et al. 2017).

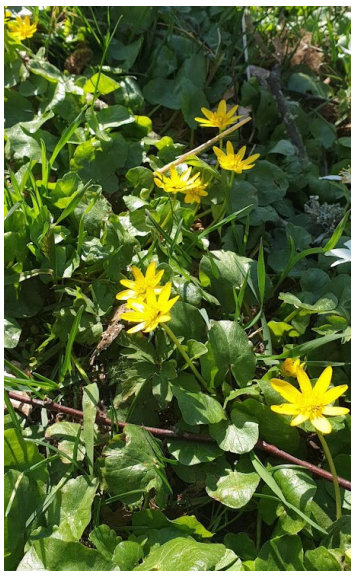

Figure 21: R. ficari (2020)

Figure 23: A.reptans (2020)

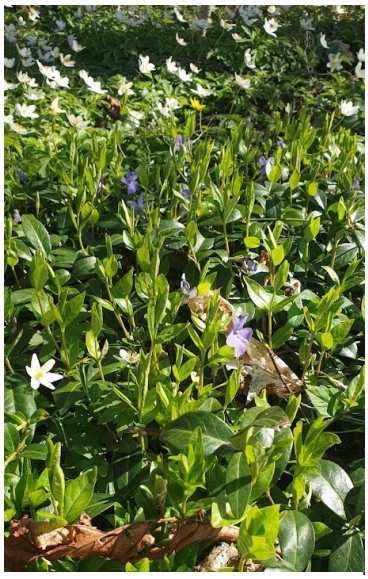

Figure 22: Mix of A.nemorosa and V.minor.(2020)

Wild bees prefer local wild species and "simple" flowers than cultivated plants in flower shops (Persson 2012; Goulson 2021). The cultivated plants sold in flower shops have been artificially deformed to adjust to humans' preferences. The plants with deformed shapes have impeded pollinators to reach the nectar and pollen and could ultimately leading to sterile flowers (Goulson 2021).

However, many exotic plant species are dependent on native pollinators (Stouffer et al. 2014). Exotic and cultivated plants do not imply that all plants have been deformed; exotic and cultivated plants are also attractive to pollinators, e.g., Begonia, Lobelias and Pelargonium (Goulson 2021). Additionally, various flowering species will typically attract various pollinators (Persson 2012; Naturvårdsverket 2018). Therefore, exotic and cultivated plants are a valuable source of forage to pollinators, and when implementing plants to new or old green structures should not be excluded.

4.2. A list of attractive plants for wild bees

The compiled lists (Tab. 1-6) are divided into two main categories: dry meadow and mesic meadow. According to Dunnet & Kingsbury (2004), the plants on green roofs will generally work on green living walls. The advisable plants on the complied list (Tab. 1-6) are for roofs with 150-300mm depth and green living walls. Most of the suggested plants are based on a literature review; all plants have not been tested in practice. The plants have been selected by reviewing the literature on green roofs, living walls or similar biotopes (dry/mesic meadow) Dunnet & Kingsbury (2004), Paju (2015) and Wahlsteen (2018). Subsequently, Persson (2012), Goulson (2021), Bee Happy Plants & Seeds (n.d.). Naturskyddsföreningen (2019), Plants for a Future (n.d.) and Pollinera Sverige (n.d.) were used to verify pollinator-friendly plants.

Abbrieviations:

HH = Various types are pollinator friendly, look at the hardiness and microclimate
Sp = Spring
Su = Summer
Fa = Fall
Wi = Winter
E = Early
M = Mid
L = Late
* = Exotic plants
spp. = species

The references refer to confirmations: to pollinator-friendly plants and plants that work well on green roofs and living walls.

4.2.1. Dry meadows

A type of meadow that can tolerate more drought than a *mesic meadow.* Lower in nutrients and humidity, suitable for exposed areas in an urban environment (Wahlsteen 2018).

Table 1. Annual/Biennials on dry meadows

Species	Common name	Flowering season	Notes
Agrostemma githago[1 2]	Common corn-cockle	Su	
Centaurea cyanus[1 2 3 4 5]	Cornflower	Su-Fa	Could also works on mesic meadows.[4]
Echium vulgare[3 5 6]	Viper's bugloss	Su	
Jasione montana[1 3]	Common sheep's bit scabious	Su-LSu	Can also be perennials. [4]
*Papaver rhoeas[1 2 3 4 5]	Vallmo	Su-LSu	HH. Can also be perennials.[4]

References: 1) Naturskyddsföreningen (2019). 2) Persson (2012). 3) Pollinera Sverige (n.d.). 4) RHS (2022). 5). Goulson (2021)

Table 2. Perennials on dry meadows

Species	Common name	Flowering season	Notes
Achillea millefolium[4 5]	Yarrow	Su-Fa	HH. Could also works on mesic meadows.[4]
*Achillea *spp.*[5]	Yarrow	Su-LSu	Could also works on mesic meadows.[4]
Anchusa officinalis[2]	Alkanet	Su-LSu	Can also be a Biennial. [4]
Armeria maritima[4 5]	Thrift	Sp-Su	HH.
*Armeria juniperifolia[4]	Thrift	Sp	HH.
*Aubrieta *spp.*[4]	Aubrieta species	Sp	HH.
*Bergenia *spp.*[4 5]	Bergenia species	Sp-Su	HH. Works well on roofs and walls.[6 7]

Campanula rotundifolia[5]	Bluebell	Su-LSu	Can be found in most part of the country, could alsoworks on mesic meadows.[4]
Centaurea scabiosa[1 2 3 4 5 8]	Greater knapweed	Su-LSu	Could also works on mesic meadows.[4]
Centaurea jacea[1 2 3]	Brownray knapweed	Su-LSu	Could also works on mesic meadows. [4]
*Centranthus ruber [4 5]	Red valerian	Su-Fa	
Cichorium intybus[1 3]	Common chicory	Su-LSu	
*Echinacea purpurea[3 4 5]	Purple coneflower	LSu-Fa	HH.The Swedish variety is 'Magnus'.
*Eryngium *ssp.*[4 5]	Sea Holly	Su-Fa	HH. Most are good for wildbees.[4 5]
*Eryngium planum[4 5]	Sea Holly	Su-Fa	Needs protection from winter wet. Could also work on mesic meadows.[4] E. planum 'Blaukappe' is more attractive to bees.[5]
*Euphorbia *spp.*[4 5]	Spurge species	Sp-Su	HH. Some varieties prefer moister conditions, more suitable more in mesic meadows or living walls.[4] E.mellifera. [5]
Fragaria vesca[9]	Wild strawberry	LSp-Su	Edible.
*Geranium *spp.*[4 5 8]	Geranium species	Su	HH. G.macrorrhizum and G. cantabrigiense works well on roofs and walls. [6 7]
Hypochaeris radicata[1 3 5]	Catsear	Su-LSu	Can also be annuals. [4]
Iberis sempervirens[4]	Candytuft	Sp-Su	HH. Could also works on mesic meadows.[4]
Knautia arvensis[2 4 8]	Field scabious	Su-LSu	
*Lavandula angustifolia[2 4 8]	Lavendel	Su-LSu	HH. Works well on roofs and walls. [6 7]

Leontodon hispidus[5]	Bristly hawkbit	Su-LSu	Similar to H. radicata.
Leucanthem vulgare[1 2 5]	Oxeye daisy	Su-LSu	
*Limonium *spp.*[4]	Statice species	Su-LSu	HH. L. latifolium & L.gmelinii. [4]
Linaria vulgaris[1 3 4 5]	Yellow toadflax	Su-Fa	
Lotus corniculatus[1 3 4 5 8]	Common bird's-foot trefoil	So-LSo	Work well on roofs. [6]
*Nepeta *spp.* [4 8]	Nepete species	Su	HH.N. 'Hills Ground', N. 'Early Bird', N. 'Chettle Blue'. [5]
Origanum vulgare[4 5 8]	Oregano	Su-Fa	Edible.
*Phedimus *spp.* [1]	Stonecrop species	Su	HH. Some species are invasive, check Naturvårdsverket's list for invasive species (Grönatakhandboken 2021).
Pilosella officinarum[1 3]	Mouse-ear hawkweed	LSp-Su	
Pimpinella saxifraga[9]	Lesser burnet	Su-LSu	
Primula veris[1 3 4 9]	Cowslip	Sp	
Ranunculus bulbosus[5 9]	Bulbous buttercup	LSp-SU	Could also works on mesic meadows.[4]
Rhodiola rosea[4 8 9]	Dark purple stonecrop	Su	Could also works on mesic meadows. [4]
*Salvia *spp.*[1 3 4 5]	Salvia species	LSp-Su	HH. Some species works better on mesic meadows, e.g., Salvia x sylvestris 'Indigo'.[5] S. nemorosa and S. officinalis are good for bees.[5]
Saponaria officinalis[1 3]	Common soapwort	Su-Fa	

*Sedum *spp.*[1 5]	Stonecrop species	Su	HH. Works well on green roofs and walls.[6]
*Sempervivum *spp.*[1]	Common houseleek	Su	HH.
*Stachys byzantina[1 3 4 5]	Lamb's ear	Su-LSu	Could also works on mesic meadows.[5] S. byzantina 'Big Ears & S. byzantina 'Countess Helen von Stein'.[5]
*Symphytum tuberosum [4 9]	Tuberous comfrey	Sp-Su	
Symphytum x uplandicum[9]	Comfrey	Su	
*Thymus *spp.*[2 8 9]	Thyme species	Su	HH. Thymus serpyllum is native. [2]
Viscaria vulgaris[1 2 3]	Sticky catchfly	Su	
*Verbascum *cvs.*[2 4 8]	Mullein	Su	HH. Some are also suitable for mesic meadows.[4]
Veronica spicata[4]	Spiked speedwell	Su	HH.[4]
Veronica officinalis[9]	Heath speedwell	Su	
Viola tricolor[9]	Wild pansy	LSp-Fa	

References: 1) Naturskyddsföreningen (2019). 2) Persson (2012). 3) Pollinera Sverige (n.d.). 4) RHS (2022). 5). Goulson (2021). 6) Korn (2022). 7) Öqvist (2022). 8) Bee Happy Plants & Seeds (n.d.) (2022). 9). Plants for a Future (n.d.)

Table 3. Bulbs on dry meadows

Species	Common name	Flower	Note
*Crocus *spp.*[1 2 3]	Crocus species	Sp	HH.[4 6] Some varieties are more suitable in mesic meadows.[6] Works well on roofs and walls.[5] 'Joan of Arc' is particularly good for bees.[4]
*Muscari *spp.*[1 2 3]	Muscari species	Sp	HH. Some varieties are more suitable in mesic meadows.[6]

References: 1) Naturskyddsföreningen (2019). 2) Pollinera Sverige (n.d.). 3) RHS (2022). 4). Goulson (2021). 5) Korn (2022). 6). Wembling (2022)

4.2.2. Mesic meadow

A type of meadow with a medium nutrient level, normal to slightly acidic pH. This meadow contains a higher humidity and nutrient level than *dry meadows* (Wahlsteen 2018).

Table 4. Annuals/Biennials on mesic meadows

Species	Common name	Flowering season	Notes
Borago officinalis[4 8 9]	Borage	Su	
*Echium plantagineu L. 'Blue Beeder'[4]	Viper's bugloss 'Blue Bedder'	Su-Fa	
Medicago lupulina[9]	Black medick	Sp-Su	Could also work on dry meadows.[4]
*Lychnis coronaria[4]	White-flowered rose campion	Su	Can be short-lived perennials. [4]
*Penstemon *spp.*[4 5]	Penstemon	Su-Fa	
*Phacelia tanacetifolia[4 5 9]	Fiddleneck	Su-Fa	

References: 1) Naturskyddsföreningen (2019). 2) Persson (2012). 3) Pollinera Sverige (n.d.). 4) RHS (2022). 5). Goulson (2021). 6) Korn (2022). 7) Öqvist (2022). 8) Bee Happy Plants & Seeds (n.d.). 9). Plants for a Future (n.d.)

Table 5. Perennials on mesic meadows

Species	Common name	Flowering season	Notes
Ajuga reptans[4 5 7]	Bugle	LSp-Su	
Anthemis tinctoria[1 4 5 7]	Dyer's chamomile	Su	Could work on dry meadows.[4]
*Aquilegia 'Colorado'[4]	Columbine 'Colorado'	Sp-Su	HH.
*Astrantia major[1 3 4 6]	Stjärnflocka	Su	HH. Might require more moisture, more suitable on living walls.[4]

*Brachyglottis *spp.*[4]	Brachyglottis	Su-Fa	HH. Will work better on locations with milder climates, zone 1(2).[4]
*Clinopodium nepeta[4 5 7]	Lesser calamint	LSp-Fa	Could also work on dry meadows.[4]
Campanula persicifolia[4 7]	Bellflower	Su	
*Erica carnea[2 4 5]	Heather	Sp	HH.
Galium odoratum[4 7]	Sweet woodruff		Should be on shady location.[4]
Glechoma hederacea[5 7]	Ground-ivy	Sp-Su	HH.
*Helleborus *spp.*[4 5]	Winter rose	Sp	HH.
*Helianthus spp.[4 5]	Sunflower species	Su	HH.
*Linaria *spp.*[1 2 3 4 5 6]	Annual marocanna	Su	HH. L. vulgaris, L. maroccana & L. purpurea.[4]
*Lysimachia nummularia[4]	Golden creeping Jenny	Su	
Hieracium aurantiacum[4]	Fox and cubs	Su	Could also works on dry meadows.[4]
*Monarda didyma[4 6]	Crimson beebalm	Su	HH.
*Oenothera fruticosa[4]	Evening primorose	Su-Fa	HH.
Primula vulgaris[4 5 9]	Primrose	Sp	HH.
Prunella vulgaris[1 2 3]	Selfheal	Su	
* Scabiosa *spp.*[4]	Small scabious	Su	Could work on dry meadows. Will work better on locations with milder climates, zone 1(2).[4] S. columbaria.[5]
Silene dioica[1 3]	Red champion	LSp-LSu	

Verbascum *ssp.* [4 5]	Mullein	Su	HH. Will work better on locations with milder climates, zone 1(2).[4]

References: 1) Naturskyddsföreningen (2019). 2) Persson (2012). 3) Pollinera Sverige (n.d.). 4) RHS (2022). 5). Goulson (2022). 6) Bee Happy Plants & Seeds (n.d.). 7). Plants for a Future (n.d.)

Table 6. Bulbs on mesic meadows

Species	Common name	Flowering season	Note
*Allium *spp.*[4 5]	Garlic species	Sp	HH. Some varieties are more suitable for dry meadows.[3 6] Good for wild bees.[4]
Eranthis hyemalis[4 5]	Winter aconite	Sp	HH.
Gagea lutea[1 3]	Yellow star of Bethlehem	Sp	
Galanthus elwesii[4]	Greater snowdrop	Wi-Sp	HH.
*Narcissus *spp.*[4]	Narcissus	Sp	HH.
*Puschkinia scilloides[1 3 4]	Striped squill	Sp	

References: 1) Naturskyddsföreningen (2019). 2) Pollinera Sverige (n.d.). 3) RHS (2022). 4). Goulson (2021). 5) Korn (2022). 6). Wembling (2022)

5. The municipalities work with the preservation of wild pollinators

5.1.1. Why municipalities and not private building owners

Green roofs and green walls have potential to enhance biodiversity in an urban environment, as previously mentioned. However, green roofs and green walls require different practical experiences and studies in the field (Mayrand & Clergeau 2018). The municipalities in Sweden can receive financial support from LONA to invest in the preservation of biodiversity projects; it is possible to receive up to 50% financial support for projects to preserve biodiversity. In addition, local authorities can initiate and be involved in these projects (Naturvårdsverket n.d.a). Other organisations, e.g., Vinnova, in cooperation with a university/organisation and Naturskyddsföreningen (SNF), also support the local authorities' development and biodiversity preservation projects (Vinnova 2022; SNF n.d).

Municipalities are responsible for the planning and development of urban structures. Municipalities also own large public buildings, e.g., libraries, schools and athletic fields (Boverket 2018). Several municipalities also own real estate companies, e.g., MKB, Burlövs Bostäder and Laholmshem AB (MKB n.d.; Burlövs Bostäder n.d.; Laholmshem AB n.d.). Despite these real estate companies' independence, the municipalities regulate the organisations (Boverket 2018). Thus, enabling the possibility to establish correlated sustainability goals, e.g., to preserve biodiversity on green roofs and green walls.

5.1.2. Incentives from Naturvårdsverket

Naturvårdsverket has decided to continue supporting and financing the preservation of the most threatened wild bees in Sweden in 2022. The counties have received the financing include: Blekinge, Gotland, Halland, Jönköping, Kalmar, Skåne, Västra Götaland and Östergötland. With one-third of the wild bees at risk owing to the lack of a nesting place, diverse flowering areas and fragmentation of forage and nesting places. *Naturvårdsverket* has decided to continue to fund the ongoing projects from 2020 to preserve the diversity of wild pollinators, essentially a part of the Swedish government's three-year incentives to support and develop the

habitat requirements for the wild pollinators in Sweden (Naturvårdsverket n.d.b). According to Naturvårdsverket (2022 n.d.c), the cooperation between municipalities, landowners and other authorities is essential for the development of the preservation of the threatened species throughout the country.

5.1.3. Conservation actions

As more people move to cities, their references and contact with nature will be through the urban environment in less formal green space, e.g., street plantings, pocket parks and green roofs and walls. It also appears that prior contact with nature is linked with conservation actions. Therefore, ensuring contact with nature through urban areas should be prioritised (Dunn et al. 2006; Fuller & Gaston 2009; Andersson 2017). Creating and restoring a native ecosystem that the public connects to could potentially form an association with the location and value the location's uniqueness (Dunn et al. 2006; Andersson 2017).

Figure 24: "Allotment Garden in Rosengård, Malmö" (2020)

5.1.4. Challenges, monetary valuation, distribution of knowledge

A study of green infrastructure and public policies with green roofs and green walls incentives highlighted the difficulties to reach the investment of private owners (Liberalesso et al. 2020). It is challenging to promote the benefits of green roofs and green walls with high implementation costs and the lack of knowledge from the building owners and the public (Andersson & Karlsson 2014; Liberalesso et al. 2020).

According to a study of monetary valuation of ecosystem services in Southampton, the UK, allocating limited public resources could be justified if local authorities were involved. Although the monetary valuation of ecosystem services could be controversial, if the public or other involved authorities could distinguish and quantify the benefits of the ecosystem services by using this approach, the argument should be considered (Collins et al. 2017). Other studies have also shown an indication of the viability of the benefits of green roofs and green walls regarding monetary valuation (Liberalesso et al. 2020).

5.1.5. Examples of projects

The BiodiverCity Project in Malmö, Scania County

BiodiverCity (Biologisk mångfald i den täta staden) was an ongoing project between 2012-2017 in Malmö, Sweden. This project aimed to preserve biodiversity by applying permanent green solutions. The green solution would be constructed and evaluated through different applications methods throughout the city to increase biodiversity, sustain and maintain greenery and deliver other urban needs. The green solutions include green roofs, green walls, urban biotopes and functional solutions for greenery (Fransson et al. 2017).

Figure 25: "Edible green wall from the BiodiverCity Project" (2022)

A survey conducted by the Swedish University of Agricultural Science (SLU) evaluated the species composition for butterflies and bumblebees in three areas in Malmö (Västra hamnen, Augustenborg and Hyllie). The survey conducted 26 green structures, 9 out of these were a part of the BiodiverCity project, to compare implemented areas to existing green structures. The survey results presented relatively low numbers of bumblebees on the established green structures within the BiodiverCity project. However, the abundance of different bumblebees on the green roofs have been found. The results also concluded that a conscious plant selection and an adequate patch size of an implemented green roof could attract both common and uncommon bumblebee species (Haaland 2017).

The Bee Connected Project in Gothenburg and Stockholm

Bee Connected is a part of the C/O city project developed by the municipality of Stockholm in cooperation with Chalmers University of Technology, SLU, the Beijer Institute. The project aimed to find a solution to maintain and support pollination in an urban environment. The focus of this project was on pollinators in urban areas, particularly bumblebees, where they worked with pocket parks. The project concluded that the local green applications such as a high diversity of flowering species would benefit more pollinators. In contrast, access to green structures in the area enhances the abundance of species. The report results also showed that it is possible to alleviate the negative impacts through the connectivity of green structures and urban planning (Berghauser Pont et al. 2017).

The Pollination project in Nybro, Kalmar County

The pollination project was a part of the urbanisation project of the city Nybror in Kalmar in 2014. The project aimed to emphasise, engage and disperse knowledge and highlight the importance of pollinators, biodiversity, quality of life, and food production in urban areas. The municipality implemented nesting places into newly established and old green structures in urban areas. Additionally, the municipality hosted events with the help of local authorities to inform and naturally induce curiosity about biodiversity. The project involved schools and organisations in planting and following the development of their plants. Other events, e.g., seminars and private organisations related to bees, were invited to teach and inspire the locals. The municipality also did inventions of the project and responded with complementary approaches in 2015 (LONA 2017).

6. Discussion

The challenges with green roofs and green living walls

The present study suggests that the increase of habitat for wild bees on green roofs and walls is possible urban areas. The study found that green roofs have been hosting many different pollinators, including bees, compared to conventional roofs. However, patch sizes, selection of plant species, height and maintenance should be prioritised if preserving biodiversity is the main ambition (Parkins & Clark 2015; Haaland 2017; Mayrand & Clergaeu 2018; Partridge & Clark 2018). The limitation of patches would decrease the effectiveness to support biodiversity (Persson 2012; Mayrand & Clergaeu 2018). However, green roofs and walls cannot be implemented on all roofs and walls, the buoyancy of old constructions might not be able to uphold the weight of these constructions.

With the increase in urbanisation and more residents moving to urban areas, buildings are bound to grow taller. The results indicate that wild bees must travel long distances and that nesting on green roofs should not be provided on the sixth floor and upwards (Persson 2012; Andersson 2017) . Although bees are a mobile species and could search for forage on higher ground from their nesting place, the issue of finding their way home remains (Goulson & Stout 2001; Mayrand & Clergeau 2018).

There are still many uncertainties about living walls, whether they could connect to green roofs to further enhance the connectivity of green structures, reduce the isolation and fragmentation between the green patches in the cities and host nests (Mayrand & Clergeau 2018). The connectivity of green living walls has scarcely been mentioned as it is incredibly complex. It requires an interdisciplinary approach. This study has refrained from further discussing the subject with the absence of other studies. Whilst this study did not confirm whether the abundance of wild bees could be found on green living walls, it can be suggested that the abundance might increase in future if the habitat requirements are met on green living walls. Further support of the idea is that there is room for further exploration of techniques in the systems, other plant species to try and ways to develop urban planning in consideration of wild bees. Therefore, a further study is suggested on

how living walls' abundance, plants and the connectivity to green roofs could enhance biodiversity.

Maintenance is another challenge that has been identified by professionals and the public, considering the opinion and current trends of designing a public space. The current trends seem to shift towards a modern approach, while the "wild" appearance of the vegetation seems less attractive to the public (Dunet & Kingsbury 2004). The seasonal changes of appearance have also been identified as an issue. However, a mutual compromise seems to have been reached when an explanation has been given. Further investigations should be carried out to establish whether this perception is reliable. This study was limited to two interviews of professional workers in the field, which has a limited scope in justifying the reliability. More interviews with workers and the public should be addressed to provide more definitive evidence.

The concept of the plant list

The methodological choices of the plant list were constrained by the time limit of the study, the absence of practical experience and examples of green roofs and green living walls. The intention of the provided plant list was to be used as a reference for further studies or experiments. The study has identified issues with the loss of native flora and fauna due to land-use change. The study also introduced the pros and cons of native, exotic and cultivated plants (Bucharova et al. 2017; Naturvårdsverket 2018; Goulson 2021; Hallman et al. 2022). It was deemed valuable to assemble and spread the knowledge of possible plants that could be used in urban planning. Considerably more work will need to be done to determine if all the suggested plants could be used and further investigate other species. A greater focus on the plant material suitable for colder climates in Sweden, of hardiness zones 4+, would be of particular interest to explore.

Why the municipalities have an important role in the preservation of biodiversity

The human-induced actions created an irrevocable process of mass species extinction; therefore, the relevance of the preservation of biodiversity should be addressed accordingly. The decline of the biodiversity of wild bees will continue to affect pollination as an ecosystem service, thus, affecting society in terms of food production, employment, sustainability and more. The results indications that if conservation actions of wild bees do not improve, the uncertainties of pollination as an ecosystem service will increase. The abundance and the ability to host pollinators on green roofs have been presented in several studies (Parkins & Clark 2015; Haaland 2017; Mayrand & Clergaeu 2018; Partridge & Clark 2018). Consequently, green roofs and green living walls have been reasonable to tackle the concern.

This thesis has provided a deeper insight into the potential local municipalities in Sweden have to contribute to future urban planning. With the accessibility to different financial support programs and public space to utilise, the possibility of dispersing knowledge about preservation through engaging events or projects is immeasurable (Vinnova 2022; Naturvårdsverket n.d.a; SNF n.d). The results also presented successful projects and the analysis of the projects (BiodiverCity, Bee Connected, The Pollination Project). The benefits of starting a preservation project imply events, dispersal knowledge and understanding to the public. However, it could also encourage enthusiasm, teambuilding and curiosity.

This study has found that the people involved in conservation activities had prior experience with nature (Dunn et al. 2006; Fuller & Gaston 2009). Therefore, the results concluded that prior contact with nature and conservation actions are essential preserving for biodiversity. The question raised by this study was whether prior contact, e.g., childhood experiences' to "wild" composition, could affect adulthoods' preferences. Thereby, introducing this landscape type to early stages would naturally induce knowledge, and if "wild" compositions became ubiquitous, appearance would not be an issue. It would further enhance the theory of whether prior experience to a "wild" composition, with preservation of biodiversity in consideration, could affect future preferences and why natural inducement of ecological knowledge is valuable.

Conclusion

This study has highlighted the importance of preserving wild bees in an urban area, particularly on green roofs. However, with the limited number of scientific studies of the green living walls, the abundance and the ability to host wild bees remains unclear. The results also showed that the green structures require connective structures between green spaces to improve the quality of implemented green structures. Nevertheless, with the improvements of the systems and further studies of different plant species, the possibility of pollinator abundance on green walls might be found. The findings of this study have practical implementations; however, the study has compiled a list of plants to study or experience within the hardiness zones of 1-4 in Sweden. Although this study suggests that the implementation of green roofs and green walls could enhance the biodiversity of wild bees, these implementations cannot replace their natural habitats. The urban environment is merely one of the existing habitats for wild bees.

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Acknowledgement

First, I would like to thank my supervisor, Christine Haaland, whose expertise and assistance was invaluable in my work. Your insightfulness has taught and inspired me throughout my work. I would also like to thank Anna Persson from Lund's University, whose presentations inspired me to write this thesis. Additionally, I would like to thank my family and friends for their continuous support, read-throughs and pictures. For this, I am incredibly grateful.