Deliverable D2.1

Guide on using the native plant communities at NBSs for urban flood resilience

LIFE LATESTadapt (LIFE21-CCA-EE-LIFE LATESTadapt/101074438)

Nordic Botanical Ltd.

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1 Introduction

This guide has been prepared as part of the LIFE LATESTadapt project (LIFE21-CCA-EE-LIFE LATESTadapt/101074438) and addresses the establishment of rain garden vegetation using native plant species. The guide serves as an initial output of the project and helps in the planning stage of rain gardens. It is important to note, however, that this material is not the final output of the project. Simultaneously with the writing of these guidelines, experiments with various plant species and plant communities are being conducted within the framework of the project in a test bed specifically established for this purpose by the project partner Nordic Botanical Ltd (Estonia) (See Fig. 1 and 2). As part of the project, a demonstration rain garden will be established in Viimsi (Estonia), which will be landscaped with plant species proven during the project, but this does not yet mean that everything important about the vegetation of rain gardens is known. It is assumed that a rain garden is a permanent structure and must function as intended for decades. Undoubtedly, various changes will occur in the vegetation of the rain garden over time, and experiences will likely be gathered from other rain gardens also established with native plants outside of the project.

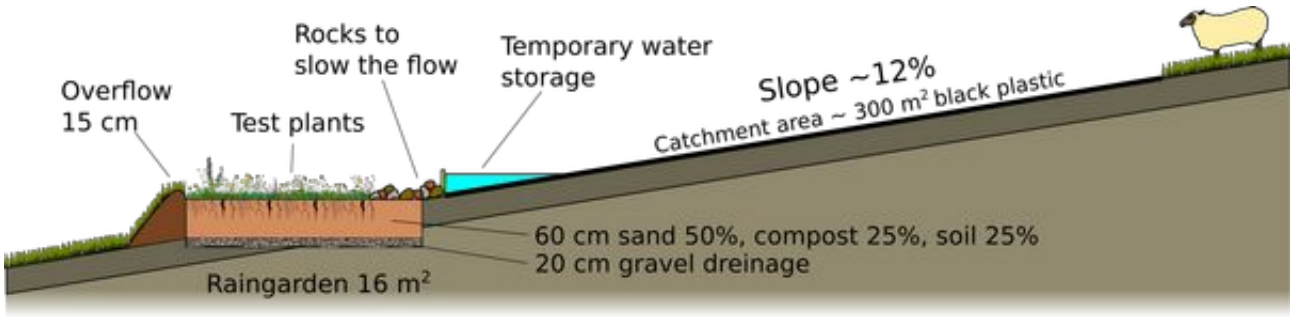

Figure 1: Scheme of Nordic Botanical Ltd. test rain garden in Vooremaa, Estonia.

There are many good summaries and guidelines on rain garden vegetation worldwide, but local specifics must always be taken into account. This includes climate, soil conditions and also the selection of local native species. While some knowledge is universal, much of it must be acquired through experimentation and experience specific to each geographical region. The following is a general overview to help select the vegetation for a rain garden and to plan its establishment and maintenance.

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Figure 2: Nordic Botanical Ltd. test rain garden in June 2024.

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2 Background. Benefits of using native plants in Green infrastructure

Developing green infrastructure in an urban environment is a modern way to simultaneously reduce traffic noise, ground and water pollution. As well as reduce landscape maintenance costs and promote biodiversity. Green infrastructure is also known to increase people's mental and physical well-being.

There are several important criteria for selecting plant species traditionally used in landscaping. Plants must primarily be aesthetically pleasing and resilient to the conditions of their future growth location. Additionally, they must be available and affordable in terms of both price and future maintenance. It can be confidently stated that traditional landscaping has not paid much attention to the nativeness of the species used or the ecosystem services they provide, nor to the aspect of biodiversity in general. The essence and aesthetics of modern landscaping solutions still trace back to a century and a half ago when non-native tree species, flowerbeds with non-native plants, and carefully manicured lawns were mainly found in manor gardens and parks. With the purchase of farmsteads in 19th century and later the independence of the Baltic states at the beginning of the 20th century, the aesthetics of manor gardens quickly spread to rural culture.

It can be said that throughout the history of ornamental gardening, garden solutions intentionally differed from the local nature. The same story was with the species selection and also the general appearance of garden landscape. Somehow the non-native garden have predominantly been considered more beautiful and native considered as boring background.

However, the context has changed significantly nowadays, and therefore, both the landscaping solutions and the selection of plant species should be reassessed. While a hundred years ago, differentiation from the general landscape and nature meant non-native species and forms not typical of the local nature, now natural and heritage landscapes have largely been replaced by modern human settlements, intensively managed agricultural landscapes, commercially managed forests, quarries and industrial landscapes. Native plant species and biodiversity have largely retreated to nature reserves and most people lack daily contact with them. Therefore, using native species in landscaping today could be seen as a continuation of the gardening tradition and once again distinguishing from the usual environment. Also as people now days rarely see native plant species, lot of them we can consider to be almost exotic.

The use of native plant species in landscaping has not entirely disappeared when it comes to trees and shrubs, and many native species are extensively used in landscaping. However, for various reasons, many native species are not utilized and imported planting material of native species or different cultivated forms are used instead. Purely natural plant-based landscaping solutions can likely be found in a few home gardens but sadly not in public green areas.

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Living in an era of biodiversity crisis, it is necessary to think about promoting and protecting biodiversity everywhere. Biodiversity, or biological diversity, is measurable at three levels:

1. Diversity of communities in the landscape;
2. Species richness;
3. Genetic diversity within species.

Of these, species richness is the easiest to assess. Plants are the cornerstone of ecosystem functioning. Various animals, from soil-dwelling worms to leaf-eating insects and their larvae, feed on them. Special attention is given to pollinating insects that feed on flower nectar and ensure the fruiting and seed production of both natural and cultivated plants. Herbivores include many mammals (various rodents, hares, roe deer, wild boar, moose) and birds (seed-eating passerines, geese) that can alter entire landscapes if present in sufficient numbers. And all the carnivorous animals from spiders, passerine birds to frogs, hedgehogs and wolfs eat usually animals that have grown eating plants. Millions of years of evolution have not only created many different plant and animal species but also refined interspecies relationships over millions of years, so usually many of other species depend on one species in nature. Sometimes these dependent species number in the hundreds.

Non-native species are those introduced by humans to a local environment where they could not have spread on their own. Generally, the direct environmental requirements of plants are relatively simple: a suitable climate, adequate nutrients in the soil, and grazing pressure no greater than on their competitors. Since a non-native species has not evolved in the environment where it grows, fewer organisms depend on it compared to native species. Often this is why introduced non-native species become invasive in their new homeland. Even when they do not become invasive, they offer far fewer habitats and resources for local biodiversity than native plant species. This fact should be considered very seriously in landscaping. Especially during the age of rapid loss of biodiversity. From the perspective of biodiversity, native plant species should always be used in landscaping. There are few situations where the native flora does not allow for a particular landscaping solution (such as a perennial vine in northern countries), but generally, the species and form richness of native plants in Estonia and Latvia is sufficient to achieve almost any landscaping solution.

In addition to preserving and promoting biodiversity, native plant species are also well adapted to the local climate and its extremes. Therefore, using native plants in landscaping is potentially more reliable and, in the long term, more cost-effective.

The availability of plant material has long been an obstacle to using native plant species. In the case of trees and shrubs, nurseries mainly offer non-native species, and the selection of native species is small and largely consists of various cultivated forms. The situation is even more complicated with native herbaceous plants. Fortunately, thanks to Nordic Botanical Ltd. (Estonia), it has been possible to buy seeds of native meadow species in Estonia for years now and there is possibility that the situation will improve also in Latvia in coming years. But the availability of planting material remains still limited. However, as consumer awareness has significantly improved in recent years, it is expected that the supply of seeds and plants on the market will improve substantially.

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3 Choosing native plant species for establishing rain garden ecosystem

Although there are ecosystems in nature that experience short-term flooding, rain gardens are unique. The tasks of a rain garden as a stormwater management solution are:

1. To extend the drainage time of stormwater to use stormwater drainage systems more evenly and efficiently;
2. Partial infiltration of stormwater into the ground;
3. Partial evaporation of stormwater through plant transpiration;
4. Partial purification of stormwater from pollutants.

Landscaping a rain garden with only native plant species adds the following values:

1. Supports natural biodiversity;
2. Is resilient to the local climate, requiring very little maintenance;
3. Provides opportunities to promote nature education.

Green solutions in public spaces must also be aesthetically pleasing. Among native plant species, there are many that bloom beautifully, and since different plant species bloom at different times, a rain garden landscaped with native plant species is aesthetically pleasing throughout all three seasons suitable for plant growth.

3.1 Natural communities that resemble rain gardens

Most naturally flooded plant communities are swampy or moist even during drier periods. In this respect, the conditions of a rain garden do not closely resemble any natural ecosystem. One of the tasks of a rain garden is to infiltrate stormwater into the soil, and therefore, materials with good drainage capabilities are used as the growth substrate for plants in a rain garden. This typically includes sand mixed with compost and natural black soil that promotes plant growth. Nevertheless, there are several natural plant communities whose conditions partially resemble those of a rain garden.

3.1.1 Coastal meadows

Coastal meadows have historically been lower and flatter areas along the coast that are periodically flooded by seawater. These areas are usually been used as pastures. The floods are primarily caused by wind, which raises the water level along the coast or in a bay when blowing directly from the sea towards the shore or a bay's mouth. The flooding of coastal meadows is not as seasonal as that of other types of flooded habitats discussed later, as the winds and their directions are more random. However, coastal meadows rise gradually above the average sea level as they extend away from the coast, and thus, the farther the meadow is from the shoreline, the less frequent the flooding. While salt-loving plant species primarily grow near the shoreline, the plant communities farther inland tend to resemble other drier meadow types. These inland plant species are not salt-loving but can

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still tolerate a small amount of salt. Salt tolerance and irregular flooding are also important considerations when selecting plant species for a rain garden, making it possible to find suitable species growing in the suprasaline zone of coastal meadows.

3.1.2 Floodplain meadows

Floodplain meadows are located along larger rivers and are prone to flooding when river water levels rise. The flooding of floodplain meadows is generally more periodic than that of coastal meadows, primarily depending on the spring snowmelt. To a lesser extent, it also depends on autumn rains and, in the case of floodplain meadows located on the lower reaches of larger rivers, on summer downpours. Floodplain meadows are usually very fertile and highly productive because river water carries a lot of nutrients from the river basin during floods.

Floodplain meadows are mostly moist even between floods and are significantly more fertile than rain gardens that are only flooded by rainwater. Nevertheless, floodplain meadows provide suitable growing conditions for many plant species that are potentially suitable for rain gardens.

3.1.3 Seasonally flooded alvar grasslands

Alvars are thin-soil meadows on limestone bedrock, which are usually very low in productivity due to the thin soil layer and underlying limestone layer, making them prone to drying out quickly. Since the limestone layer is flat and does not drain meltwater and rainwater quickly, many alvars are periodically flooded. This type of alvar, with its water regime and various other characteristics, is most similar to rain gardens. Although alvars are characterized by carbonate-rich soils, most plants growing there are not strictly lime-loving. Therefore, alvars periodically flooded by rainwater are the best natural model for designing rain garden communities. The similarities between flooded alvars and rain gardens are:

- Periodically and irregularly flooded by rainwater;
- Completely dry out during drier periods (above-ground parts of plants often dried up by mid-summer);
- Soil is fertile but thin and quickly dries out.

However, there are also differences between alvars and rain gardens:

- Soil is always lime-rich;
- Traditionally grazed.

3.2 Plant species characteristics suitable for use in rain gardens

3.2.1 Flood tolerance

As previously described, suitable plants for rain gardens cannot be true wetland plants nor plants from completely dry habitats, but rather something in between or both. Generally, plants from moist and even swampy habitats grow quite well in normal, drier garden soil, provided they do not have

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to compete with other plants and the soil is sufficiently fertile. Meanwhile, plants from drier habitats generally cannot tolerate excessively wet or water-saturated soil for long periods. This does not mean that plants from drier habitats are immediately unsuitable for rain gardens, as many of them can tolerate short-term flooding quite well, and depending on the design of the rain garden, there may be areas where floodwater rarely reaches.

Bulbous plants generally do not tolerate flooding well, as the bulbs in the soil tend to rot in constant waterlogging. However, there are some native exceptions among bulbous species that grow primarily in flood-prone coastal meadows, such as the Shingled Gladiolus (*Gladiolus imbricatus*).

3.2.2 Drought tolerance

Drought tolerance is present in some form in almost all terrestrial plant species, as natural prolonged dry periods, although rare, are experienced by most perennial plants at some point in their lives. Generally, all plants growing in a natural plant community are more or less affected by drought, and therefore, there is little risk for an individual plant that another species will gain a significant competitive advantage due to its weakening or drying out. However, if the vegetation of a rain garden consists of species that naturally grow in very different habitats, it may happen that during a prolonged dry period, species from drier habitats will take over. This aspect must be considered when selecting species for a rain garden, as the vegetation of the rain garden is expected to form a natural plant community whose biodiversity remains stable for a long time without excessive human intervention.

3.2.3 Salt (pollutants) tolerance

A certain level of salinity in floodwater is typical for coastal meadows, and the plant species there are adapted to it. However, the salinity of the Baltic Sea is very low, particularly in more enclosed inner bays (such as Matsalu and Haapsalu Bay in Estonia). The higher parts of coastal meadows are rarely flooded by seawater, and the low salinity associated with these rare floods is quickly washed out of the topsoil by precipitation. The lower parts of coastal meadows, however, are frequently flooded, and the soil salinity remains more stable. As a result, many salt-tolerant plant species grow in the lower parts of coastal meadows.

Figure 3: Nordic Botanical test rain garden during mid-winter snowmelt. The ground is frozen and does not let water to infiltrate.

Rain gardens designed to handle rainwater collected from roofs do not encounter salinity issues. However, salts (chlorides) from de-icing roads and streets can also end up in rain gardens. Unlike coastal meadows, chlorides in floodwater are a significant factor for rain gardens only during periods when active plant

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growth is absent, mainly during winter thaws and spring snowmelt. Spring rains and the soil's good drainage capacity help remove salt from the rain garden's soil. Additionally, in our northern temperate zone, it is possible for a rain garden to be frozen (see Fig. 3) and even covered with ice (Fig. 4) for most of the winter. In such cases, much of the saltier meltwater may flow through the rain garden via overflow without infiltrating the soil and affecting plant growth.

Figure 4: Nordic Botanical Ltd. test rain garden in winter 2024. All the area is frozen and covered with 10 - 15 cm of ice.

In addition to salinity, the water directed into a rain garden may contain other additives, including pollutants. These can be related to road wear (studded tires) and leaks from motor vehicles. It is expected that in most cases, the pollution load will be quite low and well diluted by rainwater. However, it can happen that after a prolonged dry period, a moderate rainfall may carry a significant amount of pollutants into the rain garden with relatively low dilution. Therefore, rain garden plants must also have some tolerance to pollution.

3.3 Ecological factors

In landscaping, the prevailing approach so far has been that all greenery must be under the control of the designer. Each species used is determined in the project, quality requirements are specified for them, and their location in the landscaping is precisely defined. However, when using native plant species in landscaping, various ecological factors and constraints come into play that are not fully under human control and do not necessarily need to be. Green areas designed to be species-rich and resembling natural meadows, indeed require very little human intervention, and minimal intervention is generally necessary from a biodiversity standpoint as well.

3.3.1 Suitable to form sustainable communities

In nature, plants can only grow together in a community if they can persist in competition with each other. Therefore, it's not possible to create any imaginable plant community. Even with plant specias that can individually grow in given conditions, because in conditions where some species are more favorable than others, the latter must retreat and typically die out after some time.

For all natural species, their suitable environment is not fully known down to the last detail, and therefore, when creating natural landscaping solutions, a large number of plant species are usually used simultaneously (30-40 species). High species richness is a characteristic of most natural ecosystems, but when creating landscaping, it must be considered that species whose environmental conditions do not suit the area being developed will die out. Ideally, potentially extinct species are not used in a specific solution, but selecting them is made difficult not by physical parameters (such as moisture, light, temperature, etc.), but rather by the interactions between species, which are difficult to predict.

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Ideally, a rain garden should form a relatively stable, species-rich plant community where the proportions of plant species remain relatively similar year after year. This means that all growing species should equally tolerate the conditions of the rain garden, and a deceased plant is replaced by a seed or vegetative renewal of the same species, similar to what happens in natural plant communities.

In reality, this is probably not entirely the case. On the one hand, due to the rain garden being an artificial structure (a kind of novel ecosystem), but also because rain gardens are often very small compared to similar natural areas. Small ecosystems are inherently less stable compared to larger ones and generally have lower species richness, primarily due to their isolation from other ecosystems containing the same species, which restricts the natural spread of species across the landscape.

3.3.2 Providing ecosystem services (biodiversity, habitats, pollination etc)

One of the most important reasons to use native plant species in rain gardens and any other landscaping is the fact that native plants provide habitats and food for other native species. This aspect is crucial in an era of rapid biodiversity loss, where using native plants helps maintain diversity and support the lives of various organisms. When selecting plant species for a rain garden, it can be assumed that all these native plant species have a similar impact on overall biodiversity (although different species may support different animal species).

For example, in the context of pollinators, plant species that provide food for honeybees or bumblebees are undoubtedly very important. However, equally important are plants that support hoverflies or beetles as pollinators. Therefore, when selecting vegetation for a rain garden, it is important to ensure that the plant diversity is high.

In addition to biodiversity, native plant species also help maintain ecosystem stability and resilience to environmental changes. Using these plants can reduce the need for human intervention and contribute to the preservation of natural processes and the promotion of biological diversity.

In summary, the use of native plant species in rain gardens and other landscaping projects is a significant step in preserving biodiversity and supporting natural ecosystems.

3.4 Practical and aesthetic traits of plant species selection

Although most of the greenery created using local natural plant species mimics some plant communities (and is expected to become indistinguishably similar in appearance and function over time), it still needs to be initially established. Not all native plant species are easily domesticated, and therefore, even with the best intentions, the created community cannot immediately resemble a natural one.

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3.4.1 Growability on gardening conditions

There are plant species for which obtaining seeds or other propagules from nature is challenging. Some species have difficulties with propagation under artificial conditions, and there are plants whose reproduction processes are so complex and lengthy that they are not viable for practical horticulture. For instance, most ferns, plants that grow in very specific habitats (such as rocky crevices), hemiparasitic and parasitic plants, certain plant families like orchids, and many other species fall into this category for various reasons. Digging plants from the wild may be easier than propagating from seeds for some species, but care must always be taken not to disturb natural habitats when establishing rain gardens. Nonetheless, plant material can be obtained from habitats inevitably affected by various developmental activities, such as logging, drainage system reconstructions, construction works, and surface mining.

3.4.2 Aesthetics

The beauty of plant species should not be the primary criterion for their selection. First and foremost, consideration should be given to whether a plant species can thrive in a rain garden, whether it can coexist long-term with other species to form a cohesive community, and whether it provides habitats and resources for other species. Only after these ecological considerations should we think about whether people potentially like the species or not. There are plant species that people have a special connection with, both positively and negatively. If possible, consideration should be given to discontinuing the use of plant species with a negative image, even if they otherwise suit a rain garden. In addition to their functional role in managing rainwater and supporting biodiversity, rain gardens are often part of public spaces and should also appeal aesthetically to people as a sustainable stormwater management solution. Ecologically, species like ground-elder (*Aegopodium podagraria*), meadowsweet (*Filipendula ulmaria*), common couch (*Elytrigia repens*), creeping thistle (*Cirsium arvense*), or dandelion (*Taraxacum officinale*) are not problematic. However, when designing a rain garden as a landscaping solution, these species should still be avoided. It's another matter if these species start growing in the rain garden regardless. In such cases, decisions must be made about whether and to what extent they can grow there without compromising public perception of rain gardens as sustainable solutions.

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4 Establishing rain garden plant communities

4.1 Rain garden design

Depending on the rain garden design and the anticipated hydrology, plant selection should be guided accordingly. Hydrology is influenced by factors such as precipitation levels, the size of the catchment area, average groundwater level, overflow design, soil drainage capacity, and the presence or absence of drainage systems beneath the rain garden.

4.1.1 Water regime

Depending on the rain garden design, there may be areas with different hydrological conditions - higher areas where water rarely reaches, lower areas where water inundation occurs more frequently, and possibly a design where the central area forms a permanent water body. This guide does not cover the latter scenario extensively as it would be more like a retention pond and considered an ecosystem resembling a freshwater body.

When a rain garden has areas with varying hydrology, it's beneficial to consider this in plant selection. Species that tolerate less inundation can be used in drier areas, while species that tolerate excess water can thrive in areas that are more frequently and deeply inundated (See Fig 5).

However, this doesn't necessarily mean that plants will remain exactly where they are planted indefinitely. Over time, the plants that establish themselves in the rain garden (not all may persist) will find their own niches where they can thrive and successfully compete with other species.

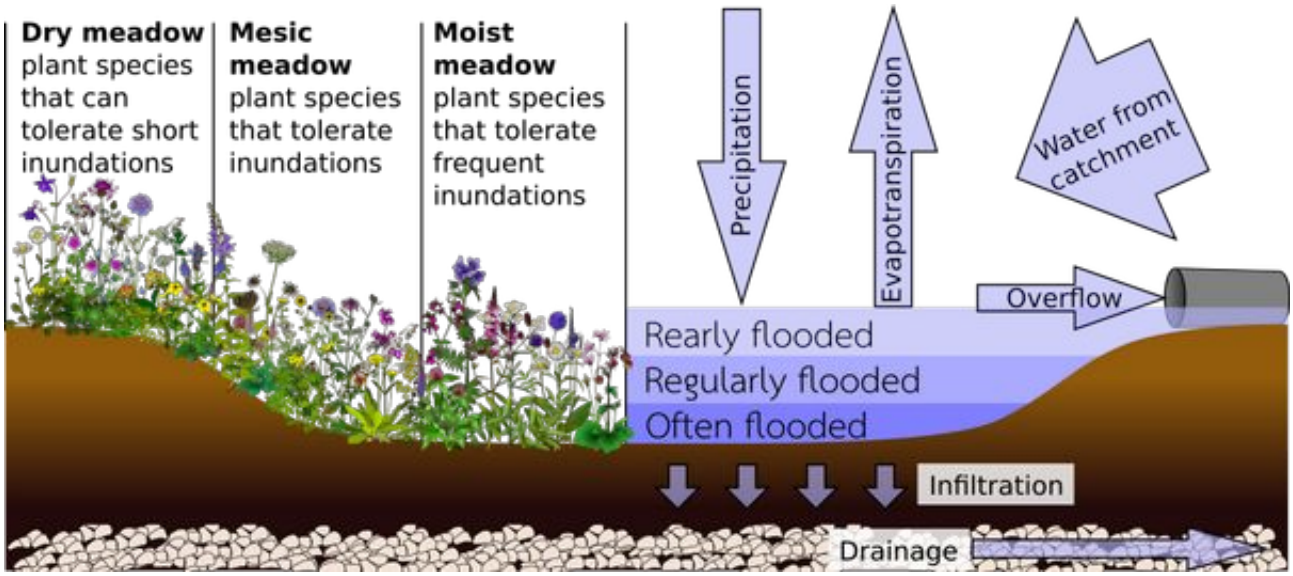

Figure 5: Rain garden zones with different moisture and flooding regime. Plant selection principles and waterflows.

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4.1.2 Growing substrate selection

The growth substrate of a rain garden typically differs from the local soil. One of the main goals of a rain garden is to absorb rainwater into the ground. Therefore, the substrate in a rain garden mainly consists of well-draining materials such as sand. Plants do not thrive in pure sand, so it is typically mixed with soil and compost. A common recommendation in literature is to mix 50% sand, 25% soil, and 25% compost. However, these proportions can vary, and the actual drainage capacity of the soil can only be determined through testing. Even tests may not provide definitive results because the effective drainage capacity of a rain garden also depends on the plants growing there, soil organisms and other factors.

It is important to assess the sand and soil for their clay content. High clay content inhibits soil permeability, while some clay content can benefit plant growth by helping the substrate retain moisture during dry periods.

Compost and natural organic matter provide essential nutrients for the vegetation in a rain garden. Native plant species in rain gardens typically do not have high nutrient demands. Water flowing into a rain garden introduces some nutrients to the plants, but it also washes dissolved minerals out of the soil into the drainage layer, where they become inaccessible to the plants. However, most of the nutrients in a rain garden are associated with living and dead biomass and the organic components of the soil. This ensures that rain gardens composed of native plant species do not require artificial fertilization.

4.2 Establishing rain garden plant community

When establishing a rain garden, careful consideration must be given not only to plant selection but also to the method of vegetation establishment. There are two main options for establishing vegetation:

Planting has some advantages:

1. The rain garden is immediately ready for use after planting, and rainwater can be directed into it immediately.
2. Planting can be done even in the middle of summer.
3. The rain garden becomes aesthetically pleasing shortly after planting and supports biodiversity (pollinators).
4. Plants digged out from natural habitats can be used.

However, planting has also some disadvantages:

1. 1. The cost of establishing vegetation per unit area is high.
2. The characteristics of the planned rain garden, expected plant species, and quantities must be known at least two growing seasons before planting (unless there is a consistent supplier of native plant material in the market).

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Establishing rain garden plant community from seeds has some advantages:

1. It is relatively cost-effective per unit area.
2. If there is a supplier of native seeds, the necessary seeds are usually readily available or have a short preorder times (maximum of six months).
3. Plant species selection can be based on the actual characteristics of the rain garden.

However, seeding has also some disadvantages:

1. Vegetation establishment takes at least two growing seasons.
2. During the first growing season, a large amount of water should not be directed to the area until the plants have properly germinated and established their root system.
3. There is a higher risk of weed proliferation in the first year of growth.

Both methods have pros and cons, and the choice between planting and seeding depends on factors such as budget, time frame, and availability of suitable plant material.

4.2.1 Establishing rain garden plant community by pre-growing and planting

When planting a rain garden with pre-grown plants, it is generally necessary to know the characteristics and area of the rain garden about two growing seasons before the planting work begins. Native plants typically have slow growth rates and may not flower in the first year of growth. However, there are species that can be adequately pre-grown in one year, but this limits the selection of species, the plants are small at the time of planting and may not establish well.

The pre-growing of plants from seeds should be entrusted to producers of native plant seeds or experienced horticultural companies. It is essential to use seeds of domestic origin (collected from nature or propagated from seeds collected from local nature) for plant pre-growing. Plants and their seeds from distant origins likely have a different gene pool, and although they belong to the same species as local native plants, they may not be as resilient under our conditions.

Plants can be planted in the rain garden in spring, summer, or fall. During drier summer periods, plants may require watering during the rooting period or prolonged droughts. Planting density does not need to be high. For most plant species, a planting spacing of approximately 10-20 cm is sufficient (50-100 plants per square meter). Most plants will grow significantly larger under favorable conditions after planting or spread via seeds and vegetative propagation, filling the initial gaps during the first year of growth.

4.2.2 Establishing plant community from seed mixtures

Establishing a rain garden from seeds is a long-term process, and predicting its outcome is also somewhat uncertain. It's best to keep heavy rainfall away from the rain garden during the germination and rooting of the plants. Typically, this means during the whole first growing season. Since the substrate has good drainage capacity and developing plants are usually sensitive to

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dryness, it's necessary to water the developing vegetation during longer dry periods. During this time, rainwater should be directed elsewhere or divert it somehow directly to the rain garden overflow.

By the second growing season, plants grown from seeds are usually well-rooted, and the surface layer of the soil has compacted enough to allow rainwater to be directed into the rain garden. However, the vegetation cover develops further in the second year and reaches its final density more towards the third growing season.

Establishing vegetation from seeds is more suitable for larger areas and areas where functionality is more important than aesthetics. This doesn't mean rain gardens established from seeds are unattractive, but flowering of the plants in such gardens takes longer, and weed growth can be a problem in the first growing season. Weeds generally diminish later on, but if the rain garden is located in a more heavily visited area, attention should be paid to maintaining its public image.

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5 Management of rain garden plant communities

5.1 Monitoring

Rain gardens are a kind of extreme habitat even for native plants. Weather extremes tend to amplify there. A rainy year is particularly wet in rain gardens, while a dry year, due to the well-draining growth substrate, becomes exceptionally dry. Therefore, predicting the rain garden plant communities performance is challenging, and monitoring rain garden vegetation is essential both for acquiring knowledge and for responding to potential issues. Understanding which species thrive better in which years, which tolerate flooding and excessive moisture, and which endure longer dry periods is crucial. Assessing the rain garden's contribution as an ecosystem service provider (such as for pollinators and recreation) and monitoring its specific parameters (like overflow versus infiltration versus transpiration) would also be beneficial. In addition to the plant species initially used in rain garden establishment, other species may naturally colonize the area. For these, their suitability for the rain garden should be evaluated. This assessment likely emphasizes aesthetic considerations, as a plant species that can survive long-term in the rain garden and its community has already proven its suitability.

5.2 First year management

Regardless of whether the rain garden is established through plantings or seedings, weeds are likely to be a problem in the first growing year. It's important to emphasize that weeds (especially annuals) are typically a temporary issue. They generally diminish from plant communities due to their low competitive ability within the first couple of years.

The amount of weeds depends primarily on two factors: the presence of weed seeds in the growing substrate (compost and soil) and the influx of weed seeds into the area.

Natural soil always contains some level of various plant seeds. Often, weed seeds persist in the soil for years or even decades, waiting for an opportunity to germinate. Agricultural soils, particularly those occasionally left fallow, often harbor many annual weed seeds. and weed control may not have been consistently applied even during prolonged storage of soil piles. Regarding compost, the quantity of weed seeds within it depends on its source and production methods (composting temperature, mixing during production etc).

Weed seeds disperse in nature through various means. Many species are wind-dispersed, while others are spread by animals. Crucially, most weeds produce a large quantity of seeds, and once established somewhere, they can quickly produce enough seeds that remain dormant in the soil, even when the plant community is dominated by perennial plants.

During the establishment year, it's crucial to keep weeds under control. There are two main methods to achieve this. The first is traditional manual weeding, suitable for smaller areas or areas established through plantings where immediate flowering of plants is desired. Weeding should ideally be organized at least twice during the summer. If possible, weeds should be removed with

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their roots, but if this is too labor-intensive or disturbs the soil too much, cutting back larger weeds may also be considered. Lower growing weeds are usually not a big problem, both practically and aesthetically.

Weeds can also be mowed. Typically their abundance is highest only in the first year, and many aggressive weeds grow faster than the plants used in establishing the rain garden. In rain gardens established by seeding, plants typically do not flower in the first year. Mowing primarily targets weeds when mowing the entire area. Additionally, weeds tolerate mowing less well than natural perennial plants. If the plant community is established through planting, those plants are also mowed. In the first year after planting, it is actually better not to mow them. Then they can root better and grow faster. Therefore, weed management through mowing is rather a maintenance method for rain gardens established by seeding.

5.3 Regular management

It is incorrect to assume that nature-based landscaping solutions are always maintenance-free. However, they generally require significantly less maintenance compared to conventional landscaping. Although a rain garden is named as a "garden," the maintenance requirements of a well-established rain garden cannot be equated to those of a flower bed. Nevertheless, it is important to note that the vegetation in a rain garden mainly consists of various plant species and resemble meadows. Without mowing, the rain garden's vegetation will gradually become species-poor over time, similar to other meadows.

Rain gardens should be mowed once or twice during the growing season. If mowing once, it should be done in the second half of July. If mowing twice, the first mowing should be at the end of May or beginning of June, and the second mowing at the end of August. Hay should be left on the ground for up to four days to allow seeds of plants to mature and fall to the ground. Afterward, the hay should be collected and removed. Regardless of when mowed, there are flowering plants in the vegetation, and often flower meadows are recommended to mow in late autumn in literature. The argument is that then all pant seeds can fall to the ground. However, perennial plants do not need seeding every Year as do annual plant species. It is actually more important to balance the competition between plant species. Summer mowing suppresses tall species and saves more smaller plants. Autumn mowing no longer balances competition between plants.

Mowing twice a year is done both times when many plant species are flowering. However, this generally does not mean a loss of floral display, as most plants will bloom again after mowing. If a rain garden is mowed once a year, a significant portion of the plants will also bloom again post-mowing. However, if mowed only once and in autumn, there's a risk that the late summer will be visually dominated by yellowing grass stems that hide flowering plants between them.

Over time, some plant species in rain gardens may change their abundance and become dominant despite mowing. Some species may disappear. It's important to always evaluate why certain species are changing in abundance. Often, this is due to natural community development, as not all environmental factors can be predicted during establishment. Since rain gardens are typically public

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installations, managing the vegetation may involve reducing overly dominant species and promoting (perhaps through additional plantings) species that otherwise struggle to compete.

In addition to mowing, debris should be removed from the rain garden. Watering a rain garden during extended dry periods is a debated practice. Using municipal water supplies for this purpose is not typically considered sustainable. Usually, native plants in rain gardens do not die due to complete soil dryness but rather enter dormancy. During this period, above-ground parts of most plants dry out, while the roots remain alive and grow new above-ground parts when rainfall resumes. However, this process takes time and can affect the competitive balance between species. Drought-tolerant species may recover better and increase in abundance over time, which may not necessarily be negative if droughts occur frequently. Similarly, species tolerant of floods may increase their abundance in years with abundant rainfall, leading to slight annual variations in the rain garden community. Actually, the same happens every year in flooded natural communities as well.

6 Overview of potential plant species

The following table includes native plant species found in Estonia and Latvia that could be suitable for a rain garden. The selection of plant species is primarily based on the following factors:

- The species naturally grow in habitats with fluctuating moisture regimes (such as coastal meadows, wet meadows, periodically flooded grasslands).
- The species are not overly demanding in terms of growing conditions.
- Many of the species listed in the table form plant communities together.
- The species are easily propagated from seed (Nordic Botanical Ltd. has experience with most of them).
- The species bloom at different times.
- The species are aesthetically pleasing.
- Several species also tolerate some level of salinity (found in coastal meadows).

The list is certainly not exhaustive, and there are likely many more suitable plant species. The use of native plants in landscaping is still in its infancy, and knowledge will continue to grow through ongoing practice.

Potential native rain garden plant species				**Known to tolerate mesic (dry) conditions**	**Known to tolerate salt (in nature)**
In English	**Eesti keeles**	**Latviski**	**Latin**		
Sneezewort	võsa-raudrohi	šķavu ķērmelīte	*Achillea ptarmica*	yes	yes
Sand Leek	metslauk	ķiploku sīpols	*Allium scorodoprasum*	yes	yes
Wild Angelica	harilik heinputk	meža zirdzene	*Angelica sylvestris*	yes	yes
Columbine	harilik kurekell	parastā ozolīte	*Aquilegia vulgaris*	yes	
Marsh-marigold	harilik varsakabi	purva purene	*Caltha palustris*	no	
Blue Sedge	vesihaljas tarn	zilganais grīslis	*Carex flacca*	yes	yes
Tufted Hairgrass	luht-kastevars	parastā ciņusmilga	*Deschampsia cespitosa*	yes	yes
Hemp-agrimony	harilik vesikanep	lielā krastkaņepe	*Eupatorium cannabinum*	no	
Meadow Fescue	harilik aruhein	pļavas auzene	*Festuca pratensis*	yes	
Red Fescue	punane aruhein	sarkanā auzene	*Festuca rubra*	yes	yes
Meadowsweet	harilik angervaks	parastā vīgrieze	*Filipendula ulmaria*	yes	yes
Hedge Bedstraw	valge madar	baltā madara	*Galium album*	yes	
Northern Bedstraw	värvmadar	ziemeļu madara	*Galium boreale*	yes	
Water Avens	ojamõõl	pļavas bitene	*Geum rivale*	yes	
Wood avens	maamõõl	pilsētas bitene	*Geum urbanum*	yes	
Irish Fleabane	pajuvaak	vītolu staģe	*Inula salicina*	yes	yes

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Potential native rain garden plant species				Known to tolerate mesic (dry) conditions	Known to tolerate salt (in nature)
In English	**Eesti keeles**	**Latviski**	**Latin**		
Yellow Iris	kollane võhumõõk	purva skalbe	*Iris pseudacorus*	no	yes
Siberian Iris	siberi võhumõõk	Sibīrijas skalbe	*Iris sibirica*	yes	
Common Rush	harilik luga	izplestais donis	*Juncus effusus*	no	yes
Autumn Hawkbit	sügisene seanupp	rudens vēlpiene	*Leontodon autumnalis*	yes	yes
Bird's-foot Trefoil	harilik nõiahammas	ragainais vanagnadziņš	*Lotus corniculatus*	yes	yes
Ragged Robin	harilik käokann	pļavas spulgnaglene	*Lychnis flos-cuculi*	yes	yes
Purple Loosestrife	harilik kukesaba	vītolu vējmietiņš	*Lythrum salicaria*	yes	yes
Purple Moor-grass	harilik sinihelmikas	zilganā molīnija	*Molinia caerulea*	yes	yes
Jacob's Ladder	harilik sinilatv	zilā kāpnīte	*Polemonium caeruleum*	yes	
Common Bistort	ussitatar	zalkšu sūrene	*Polygonum bistorta*	yes	
Tormentil	tedremaran	stāvais retējs	*Potentilla erecta*	yes	yes
Bird's-eye Primrose	pääsusilm	bezdelīgactiņa	*Primula farinosa*	yes	yes
Selfheal	harilik käbihein	parastā brūngalvīte	*Prunella vulgaris*	yes	
Meadow Buttercup	kibe tulikas	kodīgā gundega	*Ranunculus acris*	yes	yes
Multiflowered Buttercup	mitmeõiene tulikas	daudzziedu gundega	*Ranunculus polyanthemos*	yes	yes
Great Burnet	ürt-punanupp	ārstniecības brūnvālīte	*Sanguisorba officinalis*	yes	
Viper's-grass	madal mustjuur	zemā raudupe	*Scorzonera humilis*	yes	yes
Red Campion	punane pusurohi	sarkanā spulgotne	*Silene dioica*	yes	
Devil's-bit Scabious	peetrileht	pļavas vilkmēle	*Succisa pratensis*	yes	
Strawberry Clover	randristik	zemeņu āboliņš	*Trifolium fragiferum*	yes	yes
Wild Red Clover	aasristik	pļavas āboliņš	*Trifolium pratense*	yes	yes
Garden Speedwell	pikalehine mailane	garlapu veronika	*Veronica longifolia*	yes	

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