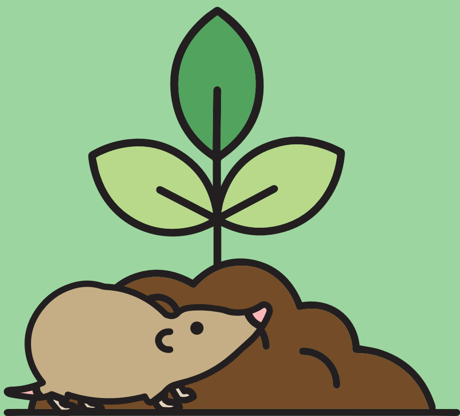
Rain Gardens



for Soil Health

Rain Gardens for Soil Health

—

Team TopSoil

Table of Contents

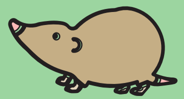
Editors’ Note

Dear reader,

We are Team TopSoil from Wageningen University & Research Student Challenge to make all soils healthy again! We have curated a booklet surrounding our project on rain gardens to use as a communication tool for municipalities looking for ways to make their cities greener, as well as individuals who stop by their local garden center looking for inspiration. Put simply our goal is to explain and spread awareness about the benefits of rain gardens. Additionally, we hope to make it as easy as possible to learn how to install and monitor them, as well as to learn about the many facets of soil health. Printed on green recycled paper and distributed along with a paper bag with a few local seeds, the book was designed to emanate sustainability from the get-go and empower people to provide practical solutions to some of the daunting environmental problems of our age. We believe in your capabilities to contribute!

Our brand icon, the shrew, walks from page to page to guide you through the booklet. While shrews are common garden creatures, our team, a group of four women, also wanted to give a little nod to the assertive and abrasive women out there who are often denoted as shrews for wholeheartedly pursuing their passions. Of course, our team could not have done it without the help of many others. We would especially like to thank James Watt and his colleagues for the feedback meetings, David Mills for creating a wonderful shrew children’s story and Angela Yang for tirelessly helping us with the illustrations and design of the booklet. From all of us, to all of you: happy gardening!

-Anna Kiers, Josephine Kooij, Kirsten Mills, Larissa Dorrestijn



Urban Soil Health

An urban green space that is under construction and will be covered in pavement, which will lead to the compaction of the soil: a major problem in cities.

Soil is the foundation of our food and standard of living.

Soils are the backbone of life on earth. They provide a growth medium for plants, which in turn creates food for animals and allows ecosystems to thrive. In just 1 m2 of soil, around 1 billion organisms may be found (Encyclopaedia Britannica, 2016). As such, it is fundamental that soils are healthy. Healthy soils are productive for their defined purpose and may be determined by a combination of soil indicators, which are expanded upon in this booklet.

Unfortunately, the world's soils are under stress from human activities as well as natural hazards, which leads to the degradation of global soils. Soil erosion contributes to large losses of valuable topsoil and agricultural practices deplete the soil of nutrients and can lead to soil compaction (WWF, n.d.). In urban areas, soils are overwhelmingly sealed off by concrete, while contamination from roadside and industrial practices lead to the pollution of the soils that are exposed (De Kimpe & Morel, 2000).

We chose to focus on the threats urban soils are facing as the amount of people living in urban areas is rapidly increasing. It is predicted that by 2050 approximately 68% of people will live in urban areas (United Nations, 2018). This provides a unique opportunity to target vulnerable urban soils crucial to human, animal, and environmental health, while simultaneously empowering a large portion of the world's population to take action against decreasing soil health. Additionally, urban areas and their soils are important for urban plant growth, wildlife, and recreation, and can be used for growing food in community gardens. These soils may create a connection between urban and rural soils, and can aid in creating a corridor of healthy ecosystems in cities.

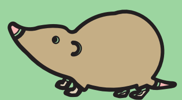
Urban soils are generally defined as soils that have been largely influenced by humans in urban and suburban areas (De Kimpe & Morel, 2000). They often differ from rural soils as urban soils are composed of material that is disposed of from nearby areas, causing the soil layers to be very diverse. To improve the health of these diverse soils, we need a solution that can be implemented on an individual scale, near roads and in public parks. We have found just the thing: rain gardens!

What are Rain Gardens?

Rain gardens are plots of land designed to withstand short-term flooding through absorbent soil that promotes drainage through the presence of native vegetation (Bray et al., n.d.). Rain gardens originated in the USA (Bray et al., n.d.), but have slowly started to become more popular in Europe. They are typically built on a gentle slope in which water runs off from the surroundings into small pond-like areas (County, 2014). Rain gardens work to absorb water, but at times of heavy rainfall, additional drains can be used to redirect excess water (County, 2014).

Rain gardens were created with the purpose of flood mitigation (Bray et al., n.d.). Worldwide, flooding causes a lot of damage to human life, infrastructure, and the environment. Over a 21-year period (1998-2009), flooding led to 1,126 fatalities and cost Europe 52 billion euros (EEA, 2010). Rojas et al. (2013) estimate that the expected annual damages caused by flooding will increase from 5.5 billion euros per year to 98 billion per year if no adaptation to climate change are implemented. Rojas et al. (2013) also explain that with adaptations put in place, this cost can be reduced to 53 billion euros per year in 2080, providing significant economic incentive for flood mitigation. Periods of flooding may be more effectively mitigated, while periods of drought may be more effectively survived as rain gardens have stored water, lessening the need for irrigation (Massachusetts Watershed Coalition, n.d.).

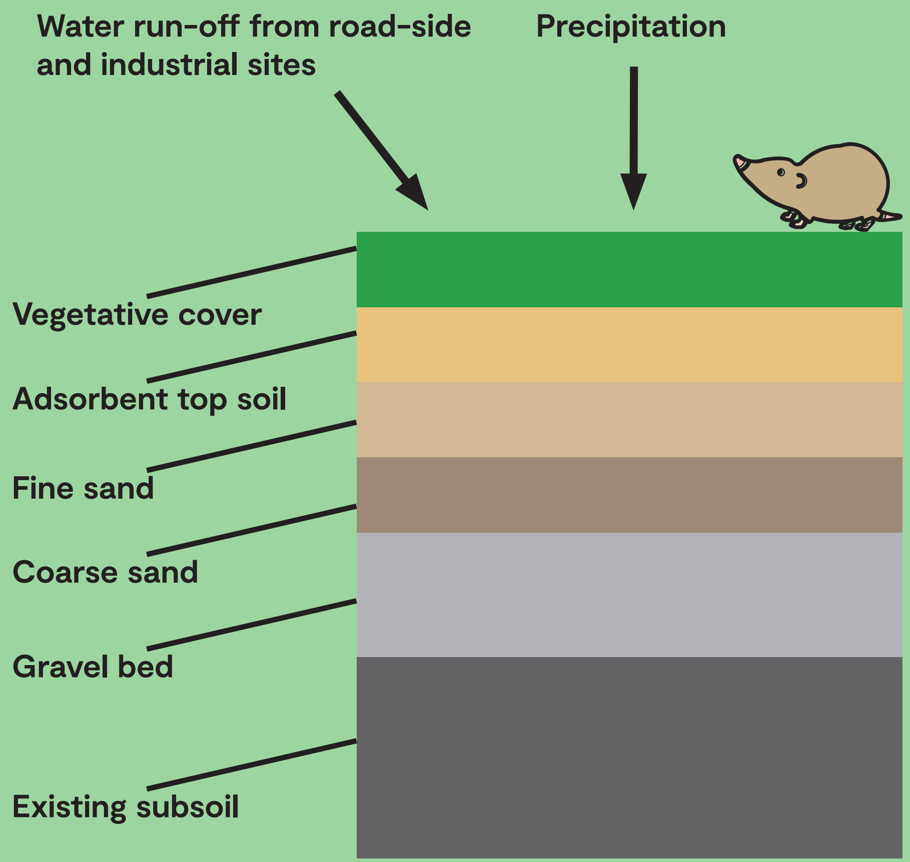
Rain gardens are also a great example of a way to improve soil health as they improve many indicators of soil health, as is described later in the booklet. They are easy to install and because of the little amount of space needed to create one, they are able to be placed in a range of different spaces (County, 2014). Multiple rain gardens together in an urban area can create a network of beautiful green spaces that may also be areas of flood mitigation, water filtration, and hubs of soil health.



Rain Garden Design

There are many guidelines for the construction of rain gardens, but these are site specific as every rain garden needs to be built and evaluated on a case by case basis. The design of the rain garden depends on whether the water will infiltrate into the soil or if the water is entering a water distribution system (Prince George's County, 2007). The rain garden should be able to drain all incoming rainwater but in the case of heavy rains, it may be beneficial to create a shallow channel at the end of the rain garden or a pipe to collect water, as these drain the water from the soil to prevent waterlogging (Gilchrist et al., 2014). It also depends on the plant species and financial capital available, as well as the size and the climate of the intended rain garden. The plant species used in rain gardens are important and should be selected based on the soil type, climate and ability to thrive in moist environments. Rain gardens should be situated far enough away from buildings (at least 1.5 m) to prevent property damage from excess water (Prince George's County, 2007). Also, it is in all cases advantageous to build the rain garden on a slight slope, but a slope of more than 20% will make construction more difficult (Prince George's County, 2007).

In rain gardens, soil is the most important aspect of the design, as soils are the materials through which the water will infiltrate. If the soil is too dense and clay-like, then it could cause flooding, which suggests there is an ideal composition of soil for the rain gardens. In the figure on the following page, optimised soil depth and texture conditions for rain gardens can be seen (Li et al., 2020). It is recommended that some sand is added to the soil composition of a rain garden if the soil is not already sandy, as sand increases hydraulic conductivity (Li et al., 2020). All in all, rain gardens may be adapted to suit different needs once some basic requirements are met. A decision tree has been made to ensure these basic requirements are fulfilled and this can be seen later in the booklet!



Rain Gardens for United Nations Sustainable Goals

There are many, many benefits of installing rain gardens! Read below to see the different aspects of urban and rural ecosystems related to the UN sustainable goals that rain gardens have an effect on.

Sustainable Cities and Communities
by increasing green infrastructure

Installing rain gardens in previously sealed surfaces has a direct effect on flood mitigation and increases green spaces in cities. Urban Heat Islands cause a localised 'island' of heat may be reduced (Siwiec, Erlandsen & Vennemo, 2018). Rain gardens promote a connection with nature in cities and the community around you, thus enhancing inclusivity and sustainable urban management. Gardening is good for human health and creates new learning opportunities in relation to nature (Soga, Gaston & Yamaura, 2017)!

Responsible Consumption and Production
through promotion of sustainability in cities

Rain gardens can promote sustainability and a connection with nature as people have better access to information about the environment and a greater awareness to allow for responsible consumption. Additionally, rain gardens may be used for growing food, thus promoting responsible production.

Clean Water and Sanitation
through pollution reduction

Rain gardens improve water quality by filtering runoff from roads and other urban infrastructure, which may include hazardous chemicals (Dietz & Clausen, 2005). Soils and vegetation act as sinks for these chemicals so that clean water may be harvested from the rain garden. Water retained in rain gardens can be stored in water distribution systems, which can in return provide valuable clean water for irrigation. Additionally, if water from rain gardens is harvested, this water may be redistributed to aid in permaculture or community farms. An example of where this is done is the Michigan Urban Farming Initiative (MUFI).

Climate Action
through flood mitigation and drought resilience

Rain gardens mitigate the effects of climate change and can be used as an educational tool for the consequences of climate change. With increasing occurrence of heavy rains as well as drought, cities need rain gardens, which serve as adequate drainage systems as well as allow for water storage during light droughts. Additionally, rain gardens can act as sinks of greenhouse gases (Shrestha et al., 2018), promoting the accumulation of these gases in the soil and out of the atmosphere.

Life on Land
through biodiversity improvement

Rain gardens promote biodiversity by attracting insects, birds and soil biota. Soil biota may range from bacteria to fungi to earthworms, improving the structure and ecology of soils. Additionally, by adding more green space into cities, it is possible to create an interconnected system of ecosystems between cities and rural areas, with better habitat for insects, birds, and plants.

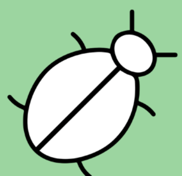
* All photos from www.un.org

Indicators for Soil Health

A range of different indicators have been determined for different soils which give a sign of how healthy soils are. The soil indicators can be grouped into three basic groups: biological, physical, and chemical.

Earthworms - Biological Indicator

An overall increase in biological activity in rain gardens ensures the increased presence of earthworms (Ayers, 2009). Through interconnectedness of ecosystems, an increase in micro- and macro-organisms stabilizes earthworm burrows and casts, thus stabilizing earthworm habitats, encouraging them to thrive (Ayers, 2009). Therefore, earthworms sustain infiltration rates within rain gardens by means of mechanically breaking up suspended solids. It is important to remember that there are levels of variability in earthworm numbers and their ability to break up solids due to varying aggregate stability (Zhang et al., 2010).



Microbial Biomass - Biological Indicator

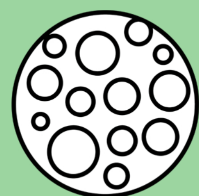
Soil profile studies showed an increase in overall biological activity in rain gardens (Ayers, 2009). This is often because the organic matter content increases within rain garden soils, leading to higher microbial function and abundance (Pavao-Zuckerman, 2011).

Infiltration and Aggregation - Physical Indicator

It is necessary to measure infiltration of the soil ahead of building a rain garden to ensure initial soil infiltration is possible so plants are able to get the nutrients and water required (Farid et al, 2019). With increased biological activity of plants, microbial biomass, and macro-organisms, water infiltration is expected to increase following adequate initial infiltration (Nimmo, 2004). This happens because soil aggregates are broken up by roots and fauna, often even if soils are compacted.

Hydraulic Conductivity - Physical Indicator

Hydraulic conductivity measures how easily water can pass through the soil. This is important because if the hydraulic conductivity is low, then soil will become waterlogged which could lead to flooding (Bouwer, 1966). Additionally, in soils where hydraulic conductivity is low there is less pollutant removal, as water is drained before removal can take place (Gilchrist et al., 2014).



Bulk Density - Physical Indicator

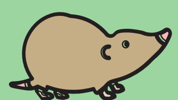
A high bulk density indicates soil compaction and leads to decreased functions of growth. The bulk density of soils should therefore decrease in rain gardens as plant roots and fauna allow for increased infiltration and slight de-aggregation (Blake, 1965).

Porosity and Water Storage – Physical Indicator

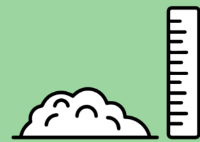
With increased infiltration (high porosity), large pathways of water flow may decrease the overall water storage of the soil. Thus, when beginning with a more permeable soil, it may be advantageous to install an underdrain below the soil or a gravel bed that slows the infiltration (County, 2014). With higher levels of aggregation in upper levels of soil, slower infiltration may lead to waterlogging, thus also necessitating the need for underdrain installation, especially in areas of heavy flooding.

Soil Respiration – Physical Indicator

Soil respiration is the production of gases from soil biota and plant roots, which occurs in all healthy soils. Overall, rain gardens have been found to act as sinks for the greenhouse gases NO2 and CO2 (Shrestha et al., 2018). This means that they have the benefit of acting as a carbon sink, helping to mitigate climate change!



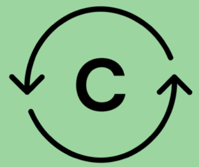
Soil depth and Texture – Physical Indicator



Soil depth is the distance from the topsoil to the underlying bedrock, or in the case of many rain gardens the bottom of the garden. It is important to have sufficient soil depth or else the water will cause flooding (Archer, 2013). The soil texture is the proportion of sand, silt and clay particles which are different sizes. This is important as different soil textures allow faster or slower infiltration, and affects other soil properties. For example, Li et al. (2020) explain that if a rain garden has a thicker layer of filler soil and if the submerged area of soil is at a moderate depth, the rain garden will have more nitrogen removal.

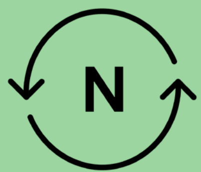
Salinity – Chemical Indicator

The rain garden may receive storm water run-off that is high in salts, especially during winter months when salt is spread on roads. Salinity of soils and water is a major limiting factor on plant growth and productivity (Parida & Das, 2005). Soils with high salinity can block the ability of plant roots to adsorb water regardless of the moisture content of the soil (Dougherty & Hall, 1995). However, many plants have adapted to be salt-tolerant, and, in soils high in salts, planting these species in rain gardens may be the best solution. Additionally, in areas with high water in flow, salinity in rain gardens may be neutralized over time.



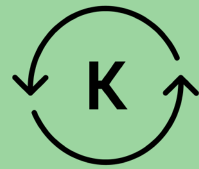
Total Organic Matter and Labile Carbon - Chemical Indicator

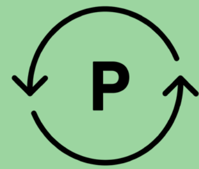
The overall organic matter is likely to increase in the rain garden over time (Cooperband, 2002). For example, earthworms can influence the availability of labile carbon and can move it up and down the soil depths (Zhang et al., 2010). This being said, organic topsoil was found to decrease contaminant removal from incoming stormwater as the pH was lower, making it more difficult to immobilise heavy metals and prevent pollution of groundwater (Good, 2011).



Available, Total and Labile Nitrogen - Chemical Indicator

Nitrogen is an essential nutrient for plants and other organisms. The available and total nitrogen amounts in rain gardens largely depends on the plant-soil interface and interactions. It is logical that stormwater or rainwater does not often contain large amounts of nitrogen (unless HNO3 acid rain is a problem in the area), especially considering the improvements in the amount of acid rain in Europe. However, it has been shown that plant detritus leads to NO3 mineralization and subsequent leaching from rain gardens (Li & Davis, 2014). In an attempt to prevent this, plant species that increase N uptake in rain gardens may be beneficial (Hunt et al., 2015). Ideally, this may promote higher overall storage capacity through high N uptake, low N leaching, high levels of evapotranspiration (Nocco et al., 2016).





Available Potassium and Phosphorous - Chemical Indicator

Potassium (K) and phosphorus (P) are essential plant nutrients. It can be assumed that leaching of available potassium and phosphorus may also occur if large amounts of water enter rain gardens. In an attempt to prevent this, plant species that increase P and K uptake in rain gardens may be beneficial (Hunt et al., 2015). Additionally, ahead of planting and creating the rain gardens, it seems important to ensure the soils are not entirely depleted of nitrogen, phosphorus and potassium as this would ensure unsuccessful growing of plants (Somaweera et al., 2017). Thus it is worthwhile to measure N, P, and K levels ahead of time.

Indicators that are more heavily dependent on incoming water and plants in the garden

There are also indicators that may be affected by the plants in the rain garden and environmental factors. For example, heavy metals and micronutrients are affected by the nutrient cycling in the soil (decomposition and growth). Additionally, if incoming water is polluted with contaminants, the soil will also become polluted over time. The pH of the soil is often also determined by incoming water (acid rain or acidic waste). This may be neutralized over time if large amounts of neutral water enter the garden.

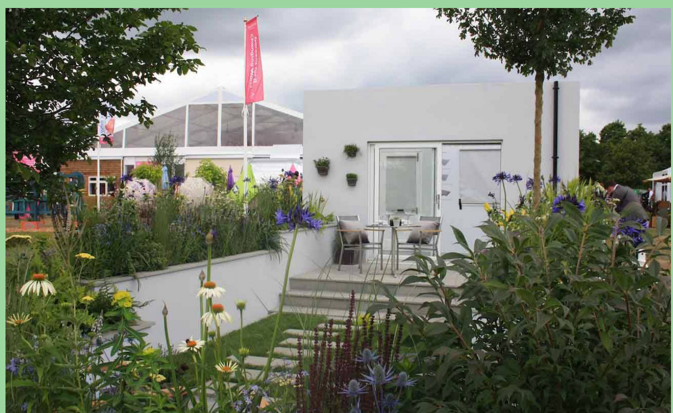
Catalogue of Rain Garden Examples

The following examples show that rain gardens can come in all shapes and sizes, can serve many different purposes, and are possible in wet and dry climates.

Individual rain gardens - gardens that are in the homes of residents, typically 10m²

Hampton Court Flower Show 2017

Size: ± 8m²
Location: Hampton Court, UK
Climate: Oceanic climate- Marine west coast climate
Site Description: This example is a show garden with many water-retaining aspects in the category of Gardens for a Changing World, for the 2017 Hampton Court Flower Show.
Achievements: Won the Silver Gilt Medal, and the People's Choice award for Best Conceptual and Gardens for a Changing World.
More info: Royal Horticulture Society (n.d.)

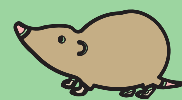


Private Danish Residence

Size: ± 25m²
Location: Brøndby, Denmark
Climate: Oceanic climate- Marine west coast climate
Site Description: Private garden where the rainwater has been diverted and can infiltrated into a rain garden with a soakaway
More info: Denmark (n.d.)

Ashby Grove Residential Retrofit Rain Garden

Size: ±2m²
Location: Ashby Grove, London
Climate: Oceanic climate- Marine west coast climate
Site Description: The rain garden is designed to remove roof water from a social housing block. The aim is to disconnect the roof downpipes so water can flow directly into the newly constructed rain garden.
Challenges: The complexity of stakeholders involved to design and construct this garden. Furthermore, it had to be checked if the rain garden did not have a negative effect on the neighbouring building.
Achievements: The rain garden is likely to have a positive effect in stabilising the clay soils in the area.
More info: Susdrain (n.d.)



Small public rain gardens - stretches of public land under 100m² in size

Nottingham Retrofit Rain Gardens

Size: 21 linear rain gardens (total of 148m²)
Location: Nottingham, UK
Climate: Oceanic climate- Marine west coast climate
Site Description: The road is adjacent to a watercourse with poor water quality. With 972 properties falling within the floodplain, these rain gardens were built to maximise surface water interception and infiltration.
Challenges: There was limited time to design the rain gardens. There was also varying support from the residents and a general lack of understanding of how surface water contributes to flooding and poor water quality.
Achievements: Initial results suggest a 33% reduction in the water flow reaching the sewer (during a storm). Furthermore, there was increased understanding and awareness of the benefits of the rain gardens, both in the community and with the partners involved.
More info: Susdrain (n.d.)

Marmax SUDSBOX

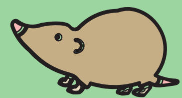
Size: about 1 m²
Location: Oslo, Norway
Climate: Warm summer humid continental climate
Site Description: The SUDSBOX is a raised bed rain garden, which can be used to help roof rainwater drainage. Nine of these boxes have been placed throughout Oslo.
Challenges: Requires some maintenance
Achievements: They can deal with about 300 L of rain water at a time and have won several awards
More info: Marmax (n.d.)

Kviberg Park

Size: 700 m²
Location: Göteborg, Sweden
Climate: Oceanic climate- Marine west coast climate
Site description: Around the multisport arena there are parking spaces for 500 cars. To catch the water flowing from the parking area, five percent of the area is used for rain gardens to clean and delay rain water.
Challenges: It is extra important to filter pollutants from the parking space since Säveån, a Natura 2000 area is close by.
Achievements: Expected impacts are cultural heritage and diversity, environmental quality and water management (SDG6).
More info: Naturevation (n.d.a)

Large public rain gardens – pieces of public land above $100m^2$ in size

Joan Reventós Park



Scale: Public - Large
Size: $20,000m^2$
Location: Barcelona, Spain
Climate: Mediterranean hot summers
Site Description: A public park that has a sustainable drainage system installed.
More info: Naturevation (n.d.b)

Lakkegata recreation park

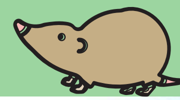
Size: $230m^2$
Location: Oslo, Norway
Climate: Warm summer humid continental climate
Site Description: The rain garden is located in the centre of the park, which is an extension of schools grounds and can be used by the public after school hours. The park has a slope towards a rain garden, where the surface water infiltrates into the ground.
Challenges: Park needed to meet the Oslo municipality water guidelines
Achievements: Designed a park that is in compliance with all criteria.
More info: Asplan Viak (n.d.)

Parque de Gomeznarro

Size : 10,000m²
Location: Madrid, Spain
Climate: Mediterranean, hot summers
Site Description: The park was renovated in 2003 to alleviate flood concerns and improve water retention in the city. The refurbishment involved; replacement of impermeable surfaces, soil structuring, re-vegetation of eroded areas, and the installation of underground storage tanks and a water distribution system. The renovations were completed over a period of six months, which were composed of three months planning and three months implementation.
Challenges: The necessary technology was difficult to acquire and collaboration between stakeholders was challenging.
Achievements: The park now collects five million litres of rain water annually, preventing the water from going into mainstream flood overflow waterways. The park won a 'good practice' qualification in 2004 by UN habitats.
More info: Climate-ADAPT (2016)

Michigan Urban Farming Initiative

Size: 12,000m²
Location: Detroit, Michigan, USA
Climate: Warm summer humid continental climate
Site Description: MUFI is a non-profit urban farming project including a community resource centre, urban farm, children's sensory garden, fruit orchid and a rain garden.
Achievements: Have supplied food to over 200 households in the past 2 years
More info: Michigan Urban Farming Initiative (n.d.)



Rain Gardens as Communication Tools

When it comes to communicating environmental problems, it is important to cater to different values, interests, and groups, as there are infinite types of people and each person reacts differently to different stimuli. For example, Corner et al. (2014) discuss how climate change communication in non-western countries is often not as individualistic as in the United States of America, so the responses to the same campaign may be very different. Relating this to the urban context, different communities within cities can have varying values and interests, so it is important to cater the communication platforms to these values. Therefore, we have decided to apply several different tools for increasing communication of soil health to different communities through:

A soil health-rain garden brand: applied to different events, areas, and initiatives in cities.

A children's story: related to the shrew and rain gardens.

Plaques: can be placed at various rain gardens around the city and used as an educational tool.

Rain garden booklet: this booklet that you are reading right now can be used as a way to spread information about rain gardens and urban soil health!

Introducing Sandy the Shrew! A Soil health-rain garden brand

The shrew can become a symbol of the presence of rain gardens within a city, but can also be applied to local events to create awareness about urban soil health. In short, it may become what the polar bear symbolizes for climate change. The goal is to promote urban soil health by creating partnerships between municipal governments and events such as marathons and festivals. We propose that the municipal government partners with Sandy the Shrew (as a brand) and apply this brand to some of the events put on by the municipality, ideally a variety of events. For example, a marathon may be organized where runners are guided along the city's public rain gardens

or a treasure hunt may be created throughout the city where children collect species from the surrounding rain gardens. Such events will ensure that different communities are reached. When the shrew initiative partners with a certain event, there can also be stands present at the events that cater to different values such as education for kids, religion, or finances.

To teach kids about soil health, Sandy the Shrew may be used to intrigue children. The shrew is a small animal that lives in plant litter and soil and eats invertebrates (Musser, n.d.) . They are fascinating animals, as they are the only land mammal that uses echolocation and they have fascinating adaptations for colder winter weather. The multifacetedness of the shrew makes it a great spokesperson for soil health. A children's story about the shrew may then be shared to engage the younger audience even further. An example of such a short story follows on the next page.

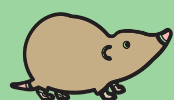
Plaques

When it comes to public rain gardens, it seems logical that plaques are used as an informative, educational tool to tell people about soil health and its importance. Some plaques may simply have eye-catching phrases such as 'Hey! This is a rain garden!' and 'I soak up rain for

the plants and critters', while others may be more informative, where each individual plaque may be related to explaining different soil indicators and their importance to soil health. The Sandy the Shrew! brand can also be applied to rain gardens within cities that can be a base for environmental education and awareness by creating plaques with Sandy the Shrew for each rain garden. Ideally, a network of rain gardens may then be created in cities to inform citizens of the benefits of rain gardens.

Booklet

The booklet which you are reading right now is another example of a communication tool that can be distributed to more groups. For example, this booklet can be distributed in a garden centre. With the explanation of the different aspects related to soil health, examples of rain gardens, and a decision tree, this booklet is a communication tool in itself. Though it is quite specifically adapted to a certain demographic (individuals and communities who are already interested in soil), it can still communicate new information that gardeners and communities may not have been aware of regarding the urban ecosystem as a whole.



Sandy the very Shrewd Shrew

Sandy the shrew was a very, very, fine shrew. With a shiny velvet coat and pointy nose, she spent most of her time looking for her favourite grub, or should I say grubs, and other creepy crawlies. She was especially fond of big, long, fat worms. The juicer the better!

Although shrews tended to keep their own company, deep down inside she loved her fellow shrews, but nevertheless kept her distance like her mum and dad. When she did get together for the occasional shrew catch-up, again just like her parents used to do, the topic of grub was never far away. And once on that topic, it was hard not to join in. Mostly the conversations went something like; "Where do you think the best places are to get the yummiest worms?", Sandy would ask. "I prefer spiders," said Silke "something with a bit of crunch". Simon couldn't disagree more, "the legs get stuck in my teeth," he said, and, "and those fangs give me the shivers..." . But always the topic came back to the same problem. "I'm sure", said Sandy "there used to be more worms". "And spiders," said Silke. They all agreed. Sandy thought a lot about this - what her parents told her and what their parents told them and she knew things were changing.

She found it difficult to put her finger on it but she said " It feels like the earth is changing." Everyone agreed that things were not the same. Silke said she felt something strange in her deep burrow when she went to sleep at night - "it's strange I know but I feel like there's a beating heart all around me." Sometimes it's soothing and I fall asleep really quickly and other times it's loud and bumpy and keeps me awake." Everyone looked at Sandy, the shrewdest of all the shrews - "I know it seems foolish but could the earth be ill?" Everyone looked at her in silence, then at each other. "If it really is ill that's very scary" said Simon. They all agreed. "What will happen?" asked Silke. Sandy, the shrewdest of Shrews had thought long and hard about the question. "Maybe" she said "we need to move, especially for the children's sake and find somewhere we feel safe and happy".

Back home, Sandy's kids knew just what to do. They formed up in a line, each shrew child grabbing the tail of its brother or sister and the first one in line catching the tail of mum. 'Beep beep' went the baby shrews, as the shrew caravan led by Sandy began to meander down the hill in search of a new and healthy home on the heath.

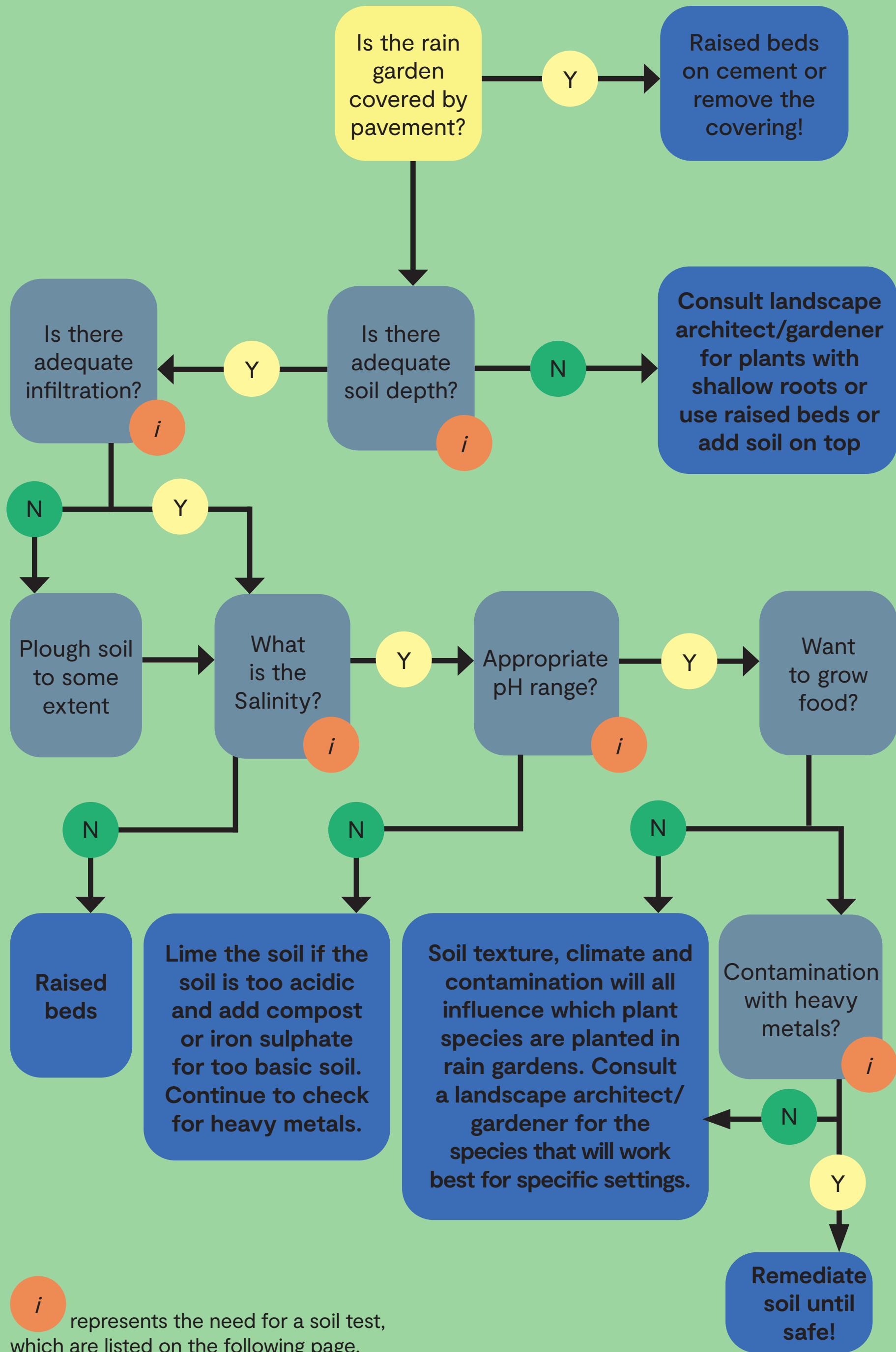
By David Mills

Communication with Policy Makers

Policy-knowledge communication platform and decision tree
The European Commission already has a joint research centre on soil information, called the European Soil Data Centre (ESDAC). The ESDAC has the ambition "to be the single reference point for and to host all relevant soil data and information at European level" (ESDAC, n.d.). On the website, the soil data available is presented in datasets, applications and maps. For example, maps visualizing the pH, saline and sodic soils and land use and cover of Europe are present. However, some of the data provided might be outdated or on a larger scale than preferred by policy makers or the general public.

This platform could be used as a basis for a soil health information sharing platform between researchers, land-owners, policy-makers and lay people. Each of these groups have either interest and/or knowledge concerning soil health. However, most of the time it is difficult to align scientific data of soils to the local knowledge of, for example, farmers about their own and surrounding lands. Part of this difficulty is caused by the different language that is used. To overcome the difference in terminology, an agreement on terminology needs to be reached between the stakeholders and different countries, similar to what is done with the Water Framework Directive (Page & Kaika, 2003). When the terminology on soils matches between different parties, communication between them will be enhanced. With this, such a soil health information platform can also make it possible for individuals who have tested the various aspects of soil health when building their own gardens to add this to the platform, so as to close potential information gaps on urban soils.

This process of testing if the soil is appropriate for building a rain garden is outlined in our decision tree, seen on the next page. It also serves as a guide for policy makers on how to design a rain garden. By asking these relevant questions regarding the existing soil, as policy makers are guided towards the tests they can use to measure the given soil parameters, the decision tree then provides the policy maker with an option on how to best design the rain garden given the outcomes on the soil indicator tests and the intended purpose of the space. For example, if the rain garden is to be used for food, the presence of heavy



i represents the need for a soil test, which are listed on the following page.

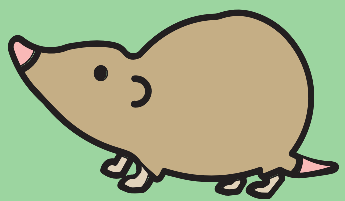
metal contamination becomes more important, as these metals may be taken up by plants. If the garden is for ornamental purposes, contamination with heavy metals is less important as they may be stored in situ in the soil. Policy-makers as well as all individuals may also check the soil health information platform ahead of building their rain garden to see if they can gain information on their soil without having to perform the tests listed in the decision tree. The missing information may then be gained through the relevant soil tests, and as a last step, a landscape architect or gardener may be consulted to decide on the appropriate plants for the given climate and landscape. Therefore, using local resources, rain gardens may be built by both individuals and policy-makers!

i **Soil tests for the decision diagram:**

Soil depth - auger hole test
Infiltration - infiltration test
Salinity - using a salinity meter
pH - using a pH meter
Contamination with heavy metals - send it to a lab

Training Manual

To further aid the policy-maker's understanding of soil health and how green spaces may improve it, a training manual detailing a four session training activity has been developed. The manual focuses on training EU policymakers in high-density urban areas and focuses on green spaces as a solution for declining EU urban soil health. The training would incorporate the sustainability competencies; systems thinking and an understanding of interconnectedness, long-term, foresighted thinking, change and innovation, and transdisciplinarity. To achieve the relevant learning objectives, four half-day sessions, over the course of one month, take place. These activities are explained in detail in the table on the next page.



Session 1 To understand basic concepts of soil health To evaluate the different types of urban green space	**Introduction:** This session would start with icebreakers. **Information Session:** An overview of the course would be provided along with all the learning objectives. **Soil Demonstration:** An outdoor demonstration on soil health showing different types of soil and health indicators. **Interactive Lecture:** Interactive lecture on soil health and information on different types of urban green space.
Session 2 To recognise the role of different stakeholders in the processes of improving soil health in cities. To evaluate the different types of urban green space	**Reflection:** Small group reflection on the previous activities. **Field Trip:** Interactive field trips visiting different urban green spaces. Travelling between the green spaces will give opportunity for discussion and reflection. Local guides will talk about the process of how these gardens were created and how the green spaces function, with a focus on soil health. **Lunch and Ending:** Lunch at a community garden, with a discussion on evaluating different types of green spaces.
Session 3 To design communication strategies to communicate with the general public about soil health To conceptually create a new unique type of urban green space	**Reflection:** Start with a reflection on the previous day's activities where the different types of urban green space are evaluated. **Think Tank:** An exercise to conceptually create new types of rain gardens. Participants work in small teams to come up with green space ideas for different urban scenarios. Furthermore, they will design strategies to communicate with the public. **Presentation:** The different groups will present their projects to each other and be given feedback. **Lunch and Ending:** Lunch with networking and reflection.
Session 4 To visualise possible futures and how to get there. To demonstrate an understanding of systems thinking and interconnectedness	**Reflection:** Start with a reflection of session 3 **Visioning Activity:** Visioning activity discussing and brainstorming the current state, possible futures, our ideal future and how to get there. A plan will be constructed detailing actions that the policymakers can take to achieve their visions for the future. **Final Reflection:** A reflection of all four sessions **Lunch and Ending:** The final lunch will provide time for networking and for participants to give feedback on the course.

Potential Rain Garden Add-ons

There are several possible add-ons to rain gardens. These can make rain gardens more inclusive, prepared for heavy rain and fun for the whole family.

Gardens and parks safe for everyone: Gardens and parks can be designed so that they are safe for all groups of people, even marginalized and vulnerable groups of people. An example of this is the Lakkegata park, which was explained in detail in the rain garden catalogue section of the booklet. The park aimed to be inclusive, especially for girls, and created large open spaces, with spaces accommodating both active and quiet spaces.

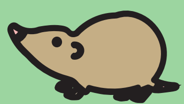
Trampoline soakaway: It is also possible to combine your rain garden with the trampoline in the backyard! Here, the section of the rain garden which collects water is hidden under a trampoline, creating more space (Water Sensitive Urban Design in Denmark, n.d.b).

Permeable pavement: It is also possible to combine permeable pavements for walking throughout the rain garden (Scholz & Grabowiecki, 2007). With this, it is possible to create the walkway in a way that ensures excess water from rain gardens may still be caught and stored.

An example of a trampoline that has a soak-away underneath it.

An example of permeable pavement.

Advanced adsorbent technology: As rain gardens are likely to absorb pollutants from roadside structure, it seems relevant to explore the possibilities of pollutant adsorbent technology. The additional costs that come with this technology may only be worth investing in if the plot of land is already polluted and will be used for food purposes, or if the land is expected to take up a large amount of pollutants (e.g. if it is located by an industrial site). Nevertheless, adsorbent technology is a growing field in remediation and may be relevant in terms of heavy metal pollution and organic pollutants (Urbano, Bustamante, Palacio, Vera, & Rivas, 2020). As adsorptive technologies for both organic pollutants and heavy metals are complex and require appropriate procedure to prevent further pollution, it is recommended that engineers and chemists are consulted before installing such add-ons in rain gardens.



Potential Rain Garden Risks

Though rain gardens have multiple benefits for soils, flood mitigation, and reaching the sustainable development goals, there are also possible risks associated with implementing them. Rain gardens require maintenance work and monitoring (Ishimatsu et al., 2016). Often with roadside rain gardens and gardens in parks it is possible that litter can accumulate which can block drainage systems (Ishmatsu et al., 2016), and can potentially affect the productivity of plant life in the garden. Additional maintenance includes weeding, making sure plants do not become overgrown, and keeping up aesthetic value.

Monitoring is necessary for the proper functioning of the rain garden, but also to ensure that the soil and the rain garden continues to be healthy. First, Asleson et al. (2009) discusses, in the context of infiltration, that monitoring rain gardens is key to ensuring that a rain garden is functioning in the best way possible. Monitoring is also important for the other soil indicators that the rain garden will impact. A second aspect of monitoring is the amount of contamination that may increase overtime in the rain garden. For example, in the case of roadside rain gardens, contamination may accumulate in the soil, and thus monitoring is necessary to ensure that the contamination does not increase past the health limits of contaminants. This is especially important for rain gardens which are built to be able to grow food.

Litter might accumulate in public gardens, which may hinder the water drainage abilities of the garden.

Mosquito's are a potential problem for rain gardens due to a possibility of still-standing water pooling around the rain garden.

Additionally, installation may be challenging. It is important to install the rain garden correctly, as incorrect installation can create issues with infiltration (Singh, 2019). However, it is possible that the implementation of non-conventional storm water sewage systems, such as rain gardens and other sustainable drainage systems, can be difficult because current policy is not geared towards these new systems of storm management (Sign, 2019). There are also additional issues to consider, such as the presence of mosquitoes if the water does not drain fast enough, as standing water can become mosquito breeding grounds (Ishimatsu et al., 2016)

There is also an opportunity cost of land associated with rain gardens. Though we argue that rain gardens are a great addition to urban areas and private residences, the land can no longer be used for other purposes. Of course the extent of this cost depends on the prior value of the land, and other possible uses for it (Siwiec et al., 2018). But as argued by Siwiec et al. (2018), an important cost that counters this is the cost of flood damages that are minimized or eliminated with the implementation of a rain garden as well as the decreased cost of contamination of other areas such as water bodies.

Thanks for learning about soil health and rain gardens with us!

Here is a ruler you can cut out to help with measuring the soil depth and the plants in your garden...

Contact the Wageningen University and Research Student Challenge: Make all soils healthy again! for more information.