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Green Infrastructure benefits of green roofs

Green roofs (https://stormwater.pca.state.mn.us/index.php?title=Green_roofs) occur at the beginning of **treatment trains** (https://stormwater.pca.state.mn.us/index.php?title=Using_the_treatment_train_approach_to_BMP_selection). Green roofs provide filtering of suspended solids and pollutants associated with those solids, although total suspended solid (TSS) concentrations from traditional roofs are generally low. Green roofs provide both volume and rate control, thus decreasing the stormwater volume being delivered to downstream **best management practices** (BMPs).

Vegetation on the Target Center Arena green roof. vegetation consisted of a pregrown Sedum mat supplemented with 22 species of plugs and 16 species of seed native to Minnesota's bedrock bluff prairies. Image Courtesy of The Kestrel Design Group, Inc.

Contents

Green infrastructure and multiple benefits

This page provides general information

Green infrastructure (GI) encompasses a wide array of practices, including stormwater management. **Green stormwater infrastructure** (GSI) encompasses a variety of practices primarily designed for managing stormwater runoff but that provide additional benefits such as habitat or aesthetic value.

There is no universal definition of GI or GSI (link here fore more information (https://stormwater.pca.state.mn.us/index.php?title=Green_infrastructure_and_green_stormwater_infrastructure_terminology)). Consequently, the terms are often interchanged, leading to confusion and misinterpretation. GSI practices are designed to function as stormwater practices first (e.g. flood control, treatment of runoff, volume control), but they can provide additional benefits. Though designed for stormwater function, GSI practices, where appropriate, should be designed to deliver multiple benefits (often termed "multiple stacked benefits"). For more information on green infrastructure, ecosystem services, and sustainability, link to Multiple benefits of green infrastructure and role of green infrastructure in sustainability and ecosystem services.

Green Infrastructure benefits of green roofs

Benefit	Effectiveness	Notes
Water quality	◔	Minimal water quality benefits due to low pollutant concentrations. Likely to leach phosphorus during first part of lifetime.
Water quantity/supply	◕	Provides rate control (detention) and volume removal (retention) through evapotranspiration.
Energy savings	◕	Provides cooling benefits in summer and heating benefits in winter
Climate resiliency	◑	Primary benefits are associated with energy savings
Air quality	◑	Vegetation can sequester pollutants
Habitat improvement	◑	Benefits are a function of access to organisms
Community livability	◔	Aesthetically pleasing but limited from public view.
Health benefits	◔	
Economic savings	◑	Associated with energy savings and life-cycle savings
Macroscale benefits	◔	Benefits are at microscale because of limited spatial extent of green roofs.
Level of benefit: ○ - none; ◔; - small; ◑ - moderate; ◕ - large; ● - very high		

Because of their use of vegetation in conjunction with building design, green roofs provide multiple green infrastructure benefits.

- **Water quality** (https://stormwater.pca.state.mn.us/index.php?title=Water_quality_benefits_of_Green_Stormwater_Infrastructure): Green roofs provide stormwater treatment benefits, but because pollutant concentrations are generally low, these benefits are limited. Pollutant removal mechanisms include filtering, evaporation, **transpiration**, biological and microbiological uptake, and soil adsorption.

  Green roofs employ **engineered media** (https://stormwater.pca.state.mn.us/index.php?title=Design_criteria_for_bioretention#Materials_specifications_-_filter_media) that is effective at removing solids, most metals, and most organic chemicals. Green roofs are generally not effective at retaining phosphorus because of the organic matter content in the media. They therefore are likely to lose phosphorus during the first years after establishment, but loss may gradually diminish over time.

  For more information see Calculating credits for green roofs and this technical support document (https://stormwater.pca.state.mn.us/index.php?title=File:Green_roof_pollutant_removal.docx).

- **Water quantity and hydrology** (https://stormwater.pca.state.mn.us/index.php?title=Water_quantity_and_hydrology_benefits_of_Green_Stormwater_Infrastructure): Green roofs are effective at detaining and retaining water and provide excellent rate control, although on a small scale. The ability of a green roof to detain and retain water is a function of both the media thickness and the sorptive properties of the media.

  For more information see Calculating credits for green roofs and this technical support document (https://stormwater.pca.state.mn.us/index.php?title=File:Green_roof_benefits.docx) and this technical support document (https://stormwater.pca.state.mn.us/index.php?title=File:Literature_Review.docx).

- **Climate resiliency** (https://stormwater.pca.state.mn.us/index.php?title=Climate_benefits_of_Green_Stormwater_Infrastructure): Green roofs provide multiple climate resiliency benefits (McCarthy and Sanchez, 2019; Santamouris, 2014)
  - They replace dark surfaces with vegetation that reflects rather than absorbs sunlight
  - Evaporation provides a cooling effect
  - For people with access to green roofs, plants can also provide shaded relief on sunny days
  - Because of the insulating value of vegetation, green roofs cool and improve heat retention during colder months. As a result, green roofs can significantly lower greenhouse gas emissions from a building.
  - Through rate control, green roofs can provide some flood mitigation, though this benefit is small
  - Vegetation on green roofs sequesters carbon, but the magnitude of this depends on the vegetation, including species and diversity, and the substrate (Whittinghill et al., 2014; Getter et al., 2009; Shafiquea et al., 2020). Deeper substrate and more complex plant communities increase sequestration over time, though initially sequestration may be slow.
- **Air quality** (https://stormwater.pca.state.mn.us/index.php?title=Air_quality_benefits_of_Green_Stormwater_Infrastructure) (Tomazin, 2014; Rudzinskas et al., 2014; Ramasubramanian et al., 2019)
  - Sequestration of carbon dioxide by vegetation was discussed in the previous discussion on climate resilience. A study in Berlin showed carbon reductions of 64-239 g/m^2, depending on plant species and coverage and media depth.
  - Green roofs effectively sequester other air pollutants, such as particulates, ozone, nitrous oxides, and sulfur dioxide. Studies in Chinese cities indicate green roofs can decrease pollutant concentrations by 5-35%, with total pollutant reductions of 85 kg/ha.
  - Green roofs may improve indoor air quality by absorbing ozone that would otherwise enter a building.
- **Habitat improvement** (https://stormwater.pca.state.mn.us/index.php?title=Wildlife_habitat_and_biodiversity_benefits_of_Green_Stormwater_Infrastructure) (Oberndorfer et al., 2007; Madre et al., 2014)
  - Green roofs provide habitat for some species of pollinating insect, some terrestrial invertebrates, and some bird species, depending on plant and media characteristics.
  - Depending on plant and media characteristics, green roofs may be used as nesting sites for birds.
  - Habitat value of green roofs varies depending on location. Accessibility can be a concern for many species. Green roof habitats can be harsh due to microclimate variability. Multiple, accessible green roofs in close proximity provide good habitat for certain species.
- **Community livability** (https://stormwater.pca.state.mn.us/index.php?title=Social_benefits_of_Green_Stormwater_Infrastructure)
  - Green roofs are aesthetically pleasing, though they are typically not visible to the general public. A variety of vegetation can also be used, including perennial plants, shrubs, and trees.
  - Green roofs can increase sound insulation, fire resistance, the longevity of the roof membrane, and reduce the energy required for the maintenance of interior climates.
  - Green roofs represent significant potential for food production in terms of available space, but there are limitations due to harsh microclimates and fertilizer and water needs (Harada, Y. and Whitlow, 2020).
  - Several studies indicate a correlation between green space and social benefits, including lower crime, improved health, and increased social interaction (Mesimäkia et al., 2017; Orberndorfer et al., 2007).
- **Health benefits** (https://stormwater.pca.state.mn.us/index.php?title=Social_benefits_of_Green_Stormwater_Infrastructure): (Ramasubramanian et al., 2019)
  - Green roofs may improve indoor air quality by absorbing ozone that would otherwise enter a building.
- **Economic savings** (https://stormwater.pca.state.mn.us/index.php?title=Social_benefits_of_Green_Stormwater_Infrastructure) (Oberndorfer et al., 2007)
  - Although green roofs are initially more expensive to construct than conventional roofs, they can be more economical over the life span of the roof because of the energy saved and the longevity of roof membranes.
  - Because of the insulating value of vegetation, green roofs cool and improve heat retention during colder months. As a result, green roofs can significantly lower energy costs for a building.

Design considerations to maximize multiple benefits of green roofs

Maximizing specific green infrastructure (GI) benefits of green roofs requires design considerations prior to constructing the practice. While site limitations cannot always be overcome, the following recommendations maximize the GI benefit of green roofs. An important design consideration for many green roof benefits is vegetation. For more information, see Plant lists for green roofs.

Caution: The following discussion focuses on design considerations. All benefits delivered by the practice require appropriate construction, operation, and maintenance of the practice. O&M considerations should be included during the design phase of a project. For information on O&M for GSI practices, see Operation and maintenance of green stormwater infrastructure best management practices

- Water quality
  - Because of low pollutant concentrations, green roofs have limited impact on reducing pollutant loads in stormwater. However, the engineered media for green roofs may leach phosphorus. Low organic matter media, media that does not leach phosphorus (e.g. peat), or amendments (e.g. iron filings) may minimize or eliminate phosphorus losses from green roofs.
- Water quantity/supply (Bollman et al., 2019)
  - Increase media depth to extent economically feasible
  - Maximize the sorptive and retention properties of the media. Increasing the organic fraction can increase water retention but may result in phosphorus export and other concerns if drying occurs. Additives such as perlite and pumice increase water retention. See Bollman et al., 2019 (https://www.ncbi.nlm.nih.gov/pmc/articles/PMC6997945/))
- Climate resiliency (Dvorak, 2021; Shafique et al., 2020)
  - Select a variety of plants adapted to different microclimates. This increases likelihood that plants will remain established in situations where the climate or microclimate changes. Include at least 15-20 taxa of plants that are native to a variety of microclimate conditions, including a mix of annuals and perennials. Leaf area index is a good indicator of sequestration potential.
  - Increase plant diversity, growing a mix of types (e.g. perennials, annuals, bulbs, etc.) and forms (e.g. height, coverage). Include prostrate and upright forms of plants to allow vegetation to compete for its preferred niche on a green roof.
  - Utilize nature-based approaches similar to the ecoregion in which the green roof exists
  - Incorporate grasses into the landscape as they are deep-rooting and drought tolerant
  - Select vegetation that has high root biomass
  - Use light-colored mulch to avoid excessive heat gain to the substrate and help retain moisture in the substrate
  - If irrigation is used, moisture sensors should be included in zones to help conserve water and prevent overwatering of the substrate.
- Habitat (Dvorak, 2021; Oberndorfer et al., 2007)
  - Incorporate annuals into plant selection. Many annuals are important pollinators that can self-sow into bare areas. Since many annuals complete their life-cycle during one season (spring, or summer), it may be necessary to include several species of annuals to have plants actively growing in multiple seasons. Examples include bluebonnets (*Lupinus texensis*), Indian paintbrush (*Castilleja*), Firewheel (*Gaulliardia pulchella*), and black-eyed Susans (*Rudbeckia hirta*).
  - Employ a mixture of small shrubs, grasses, and sedums, each occupying complementary niches.
- Community livability
  - Food production can be enhanced by utilizing rooftop greenhouses, which extends the growing season and creates an environment where fertilizer inputs and microclimate can be controlled and the growing season extended (Harada and Whitlow, 2020). Use of potted vegetation also allows for greater control of these factors. Herbs are less dependent on media thickness and are more adaptable to green roof conditions than vegetables.
  - Use of a harvest and reuse system (called blue-green roofs) allows for greater control of microclimate factors and can improve food production and plant resiliency (Cristiano et al., 2021).

    - Form and function are important considerations for perceptions of green roofs. For example, work buildings can incorporate resting areas for workers, while large buildings can incorporate walkways and lush vegetation (Mesimäkia et al., 2017). End users and their desires should be considered in the green roof design.
    - If social interaction is an objective, landscape should be considered. This may include a variety of vegetation of differing heights, including flowering plants (Mesimäkia et al., 2017).
- Health benefits
    - Maximize media thickness and select plants that are effective at sequestering pollutants
- Economic benefits (Sailor et al., 2011; Cristiano et al., 2021)
    - Increasing media depth and use of light-colored reflective material in areas lacking vegetation results in greater energy savings.
    - Captured water may be used to cool and warm buildings.

Recommended reading

These articles provide more high level but thorough discussion of benefits of green roofs.

- 10 Reasons Why Green Roofs Are The Wave Of A Climate Resilient Urban Future (https://medium.com/future-proof-cities/10-reasons-why-green-roofs-are-the-wave-of-a-climate-resilient-urban-future-c0156adb5826) - Danny Schleien, 2021.
- GREEN INFRASTRUCTURE: GREEN ROOFS AND WALLS (https://www.asla.org/contentdetail.aspx?id=43536#:~:text=Green%20roofs%20can%20help%20regulate,heating%20and%20cooling%20energy%20savings.) - American Society of Landscape Architects
- About Green Roofs (https://greenroofs.org/about-green-roofs) - Green Roofs for Healthy Cities
- Soak up the Rain: Green Roofs (https://www.epa.gov/soakuptherain/soak-rain-green-roofs) - US EPA
- ACCESS TO GREEN INFRASTRUCTURE: A LOOK AT EQUITY IN GREEN ROOFS (https://mdp.berkeley.edu/access-to-green-infrastructure-a-look-at-equity-in-green-roofs/) - University of California, Berkeley

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