Review of the application of green infrastructure for water management in Bogor

What is Green Infrastructure?

Green and blue infrastructure also known as green infrastructure (GI), is a suite of nature-based technologies using plant and water systems, that can be used in urban designs to deliver a range of essential water management outcomes. In a water sensitive city model, GI is used for storm water treatment, flow attenuation (control) and storage for re-use. GI can also provide secondary benefits such as improving the look and value of the landscape, urban cooling and flood mitigation. Most green technologies are multi-functional, and can be applied at a range of scales and used for a range of applications. With these benefits, GI can help strengthen Bogor's economy and improve the health and quality of life of its residents. Several countries across the globe now recognise that GI is critical to the health, liveability and sustainability of urban environments.

Green infrastructure in Bogor, and in a tropical climate

Bogor's abundant natural greenery, hundreds of natural lakes, famous botanical gardens, and reputation as the 'Rain City' suggest it is ideal for transformation to a Water Sensitive City through the integration of GI into city development plans to tackle the city's challenges such as dry season water shortages, flooding and water management.

Bogor's tropical climate offers both opportunities and challenges for water management, for example:

- The warm and humid climate allows for rapid plant growth and generally higher biological activity all year, but also provides favourable conditions for mosquitoes and various diseases.
- Tropical rain patterns (high intensity) provide ample rainwater for many uses, but seasonally too much rain for the landscape to process causing erosion, flooding and pollution.

See the front section of this booklet for more discussion of Bogor's particular characteristics and trends and see the full Green Infrastructure report for an in-depth look at the challenges and opportunities in applying green infrastructure to Bogor.

The multiple benefits provided by Green Infrastructure

Environmental

- **Water quality** treatment (through pollutant removal)
- **Flood mitigation** (by reducing flow)
- Protecting **human and ecological health**
- Providing a **source of water** for re-use (through stormwater harvesting or greywater treatment & re-use)
- Enhancing **water security**, resilience & reducing demand on other water sources
- **Urban greenery, biodiversity & amenity**
- **Groundwater recharge** through infiltration

Socio-Cultural

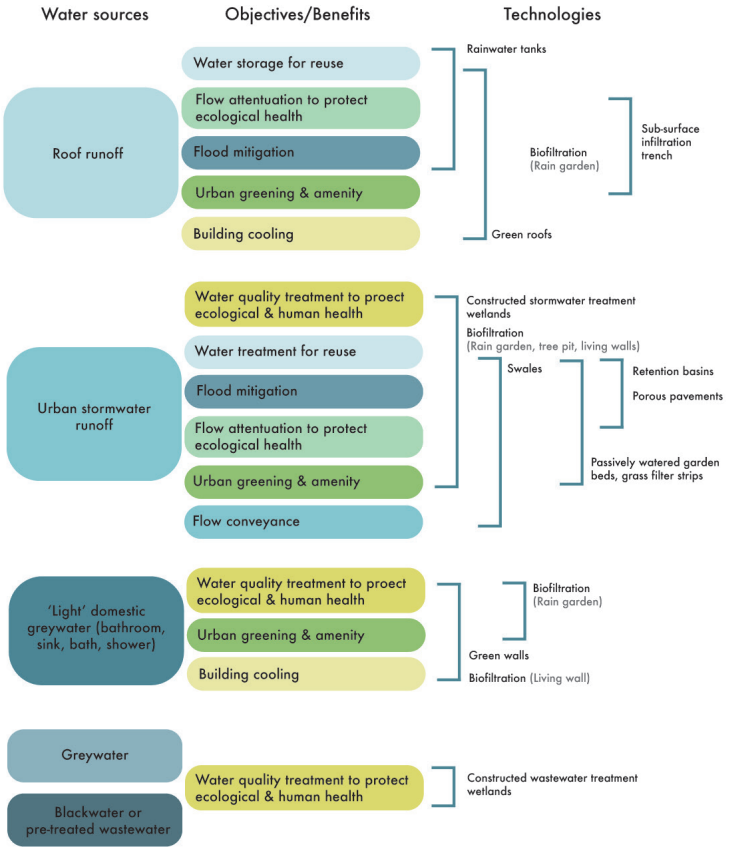
- Enhancing **human wellbeing and health**
- **Cooling** the city's microclimate & buildings
- Providing **habitat** for flora and fauna

Economic

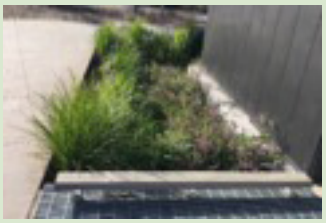
- Increased **property values and avoiding future costs** for remediation and grey infrastructure
- Possible **economic benefit** from harvested plants for products or food

Selecting which Green Infrastructure systems to use

Green infrastructure measures to treat, control or store water sources, should be selected based upon the individual site characteristics, urban planning, objectives and/or co-benefits that are important for the community or city to achieve (see chart below).



Descriptions of green infrastructure (GI)



Biofiltration/bioretention/ raingardens

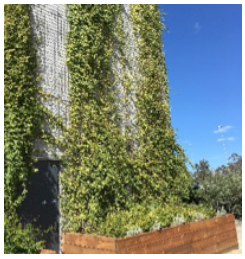
Vegetated filters, designed to capture, detain and infiltrate stormwater or greywater before it is either collected for appropriate reuse, infiltrated into surrounding soils or discharged into the drainage or sewer system.

Treepits

A type of raingarden planted with trees, often located along streets collecting runoff from the road or pavement. This provides stormwater treatment, reduced runoff, passive irrigation of the trees, amenity, shading and cooling of the streetscape.

Constructed wetlands

Man-made shallow and densely-planted water bodies that retain and filter water for discharge into lakes and rivers or for re-use.

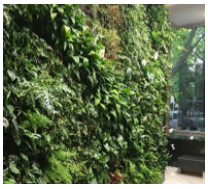


Living walls (or green façades)

A type of vertical greening system consisting of climbing plant species growing directly onto a building façade or on an external structural supporting system adjacent to the wall. They are a type of biofiltration system with plants growing directly into the soil or in planter boxes at the base of the wall.

Green roofs (or living roofs / roof gardens)

Roofs covered with vegetation growing in a specifically designed growing medium and separated from the roof structure via a waterproof membrane.



Green walls

Vertical gardens with shallow-rooted plants grown in compartments or modules filled with light-weight growing substrate and attached onto wall surfaces.
They provide thermal insulation and cooling but need a substantial amount of water to remain lush and green. Harvested roof runoff or greywater generated by the building can be used to water the green wall, and in turn receive treatment by the green wall if in excess of its irrigation demands.

Swales/buffer strips

Vegetated channels that convey rainwater to the drainage/sewer system. During the process, they help to slow down and partially infiltrate rainwater. They are often used alongside roads and as a pre-treatment measure for downstream GI systems such as bioretention systems.

Riparian buffers

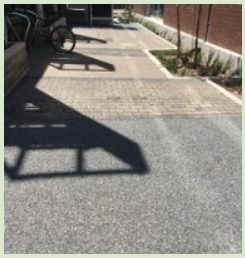
Vegetated areas along the banks of rivers and lakes to protect the water quality of the water body. They help prevent erosion and are an important food source for fish populations. They include trees, grasses, groundcovers.

Sedimentation ponds/basins

Water bodies that capture coarse sediments and litter washed off during storm events. They are usually employed as a pre-treatment measure to wetland systems.

Retention ponds or retarding basins

Artificial water bodies, lakes or empty depressions that help retain water during a storm event to prevent downstream flooding and erosion. Ponds usually retain some water permanently. Retarding basins may be empty, or partially empty, between storm events which can allow recreational use of the space.



Porous pavements

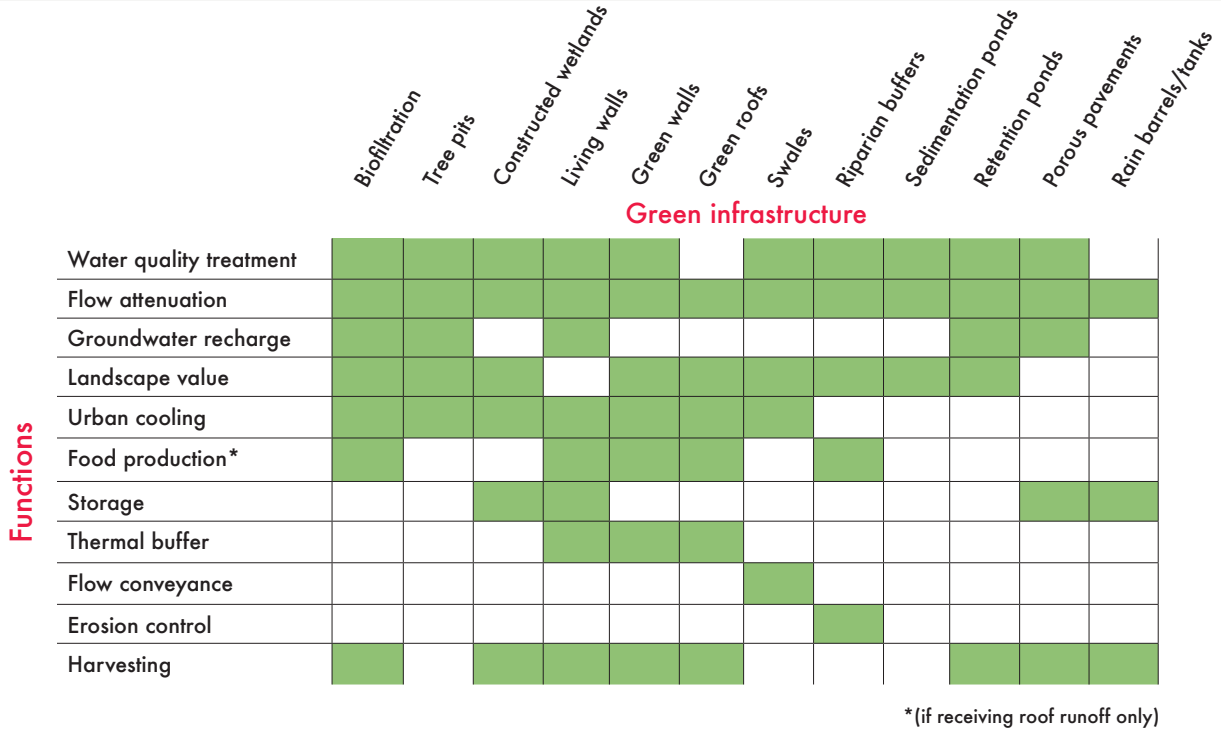
Alternative paving surfaces that allow water to percolate through permeable layers. Water can either infiltrate into the surrounding soils or be discharged into the drainage system.

Rain barrels/tanks

Above or under-ground storage facilities, typically used in residential lots to retain rainwater from roofs on-site. The rainwater collected can be re-used for non-potable domestic use or irrigation, discharged to the drainage system or infiltrated into the surrounding soil.

Functions of GI

The functions of each technology are illustrated to the right, while examples of their application to solve common problems in Bogor's urban environment can be found below.



*(if receiving roof runoff only)

Applications of GI

Example problem/s	Example GI	Example application as a solution
Impervious surfaces & concrete drains » Flooding » Poor water quality & erosion in local streams, rivers or situs » Minimal urban greenery	» Biofiltration/ bioretention/ raingardens » Tree pits » Constructed wetlands	» Reduced runoff volume for reduced flooding & erosion downstream » Stormwater treatment for reduced pollution, healthier waterways » Groundwater recharge if system unlined to promote infiltration » Urban greenery & amenity for enhanced community well-being & real-estate value » Wetlands can provide storage for stormwater harvesting
» Impervious surfaces leading to flooding, pollutant conveyance » Growing water demand and limited supply	» Sedimentation ponds/ basins » Retention ponds or retarding basins	» Storage for flooding mitigation, some water treatment » Ponds provide storage for stormwater harvesting
» Impervious surfaces and concrete drains leading to flooding » Conveyance of urban pollutants downstream	» Swales/buffer strips	» Vegetated swales and biofilters for water treatment, flood mitigation, urban greenery

Selecting Plant Species for Green Infrastructure

An abundance of healthy plants are the key to effective functioning of green infrastructure. In Bogor, there are many local and widely cultivated plant species available to drive many of the benefits delivered by green infrastructure; water quality treatment, flow attenuation, greenery, amenity, biodiversity, urban cooling and human health and wellbeing. Some plants also have economic uses.

Plant species will vary in their capacity to survive, grow and provide these different functions. Desirable plant characteristics and some examples are illustrated in the figure to the right. For more information, including a comprehensive list of plant species recommendations across technologies (including plants to generally avoid), see full Green Infrastructure report and its Appendix.

✓ Locally available from nurseries

✓ Suited to local climate

✓ Tolerant of conditions expected within the system:

- » Expected dry periods (in biofilters, green roofs)
- » Temporary inundation (in biofilters, swales)
- » Inundation regime and water level changes (wetlands)
- » Flow velocity (Swales, entrance of biofilters, wetlands)
- » Capacity to grow in media (sand in biofilters)
- » Suited to the particular site/location and media depth

✓ General desirable plant characteristics:

- » Appropriate size for green infrastructure
- » Hardy
- » Adaptable to a wide range of conditions
- » Relatively high growth & plant productivity
- » Extensive root systems
- » Low maintenance
- » Useful economic purposes

✓ Select multiple species (diversity) and various plant types/growth forms

Biofiltration systems:

Syzgium polyanthum (**Salam,** Indonesian bay leaf)
Tree
Myrtaceae

✓ (Easy to grow, adaptable, grows on roadsides, economic uses)

Living walls:

Bougainvillea 'Sakura Variegta' (Bougainvillea)
Climber, shrub
Nyctaginaceae

✓ (Popular, common, hardy, ornamental, very effective for nitrate removal in Singapore testing. *Note – potential to damage buildings with thorns)

Key findings:

- » Green infrastructure has been demonstrated to be effective in tropical climates for water quality treatment, flow attenuation and other benefits.
- » GI has been successfully adopted in other tropical locations such as Singapore, Malaysia and northern Australia, and local guidelines have been developed for handling the advantages and challenges presented in those areas.
- » There are solid foundations for the adoption of GI in Bogor, with examples to build upon, existing local skills and resources, and natural green and blue assets. The four case studies have also highlighted how multiple issues can be mitigated by green infrastructure.
- » With high rainfall, rainwater harvesting for non-potable uses offers significant potential to diversify Bogor's water sources – helping to ensure a more sustainable and resilient water supply. For example, roof runoff can be used for irrigation of urban agriculture while simultaneously reducing flooding and demands on traditional water sources and improving urban greenery, nutrition, the local economy and community resilience.
- » Treated greywater through GI systems could also provide an alternative water source, for toilet flushing, irrigation or other appropriate end-use applications and would help reduce wastewater discharge into rivers and lakes.
- » Plants are critical to many functions within GI systems. In Bogor there are many local plant species that offer potential with many plants also associated with potential economic uses. Plant selection is vital.

Recommendations for future work include:

- » Further testing of the performance of GI systems under local conditions to help refine design and plant species selection.
- » Development of a standardised document to facilitate implementation and design of green infrastructure in Bogor, including target design objectives.
- » Further investigation of the potential for stormwater or greywater systems to be safely used for food production.