Università di Genova

Greening the Grey: Leveraging the Potential of Bioretention Cells to Tackle Urban Flooding

22 MARCH WORLD WATER DAY 2024 Water for Peace

Water for Peace

Background

The challenges posed by global population growth and rapid urbanization, as well as climate change, necessitate a paradigm shift in urban stormwater management. Additionally, conventional drainage systems are proving ineffective in handling the increasing volume of stormwater runoff, erosion, scouring, and addressing management practices [1, 2]. In this context, Low-Impact Development (LID) has been widely considered to deal with these issues, and among all LIDs, Bioretention Cells (BRCs) are a promising practice commonly used in urban settings. Figure 1 shows principal physical, chemical and biological mechanisms occurring in BRC [2].

While extensive monitoring research has demonstrated the suitable performance of BRCs in terms of quantity and quality at the laboratory or site scale, the link between these site-scale impacts of BRC and catchment-scale in urban areas remain unclear. To effectively restore urban stream flow patterns and hydrologic processes to pre-developed levels, as required by the principle of hydraulic and hydrologic invariance, it is imperative to understand how the effects of BRCs observed at the site scale translate to catchment-scale effects [2, 3]. This research study intends to address this gap by answering the overarching research question

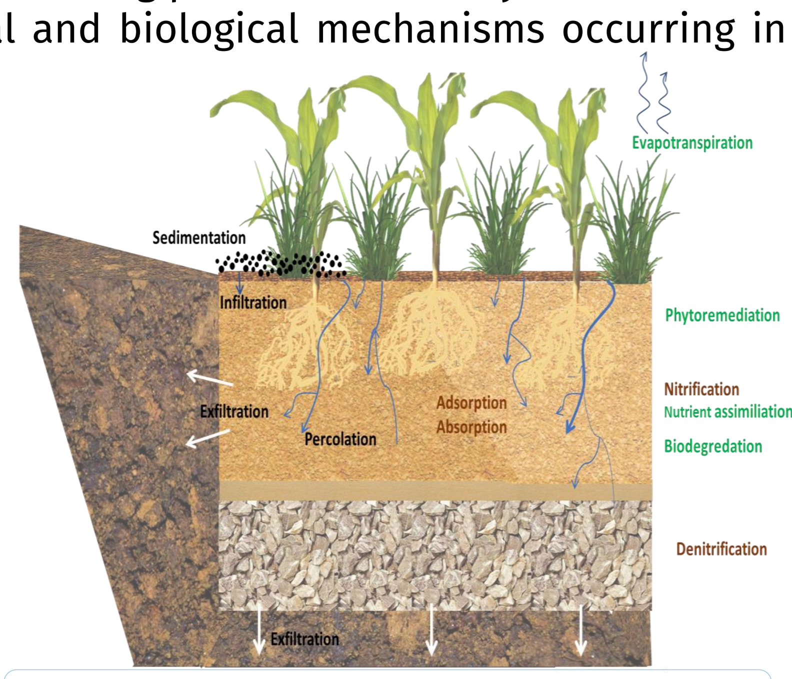


Figure 1: physical (black label), biochemical/chemical (brown label), biological (green label) mechanisms that occur in BRC [2].

"How does implementation of BRC in urban catchment impact urban hydrology process and flow regimes?"

Objectives

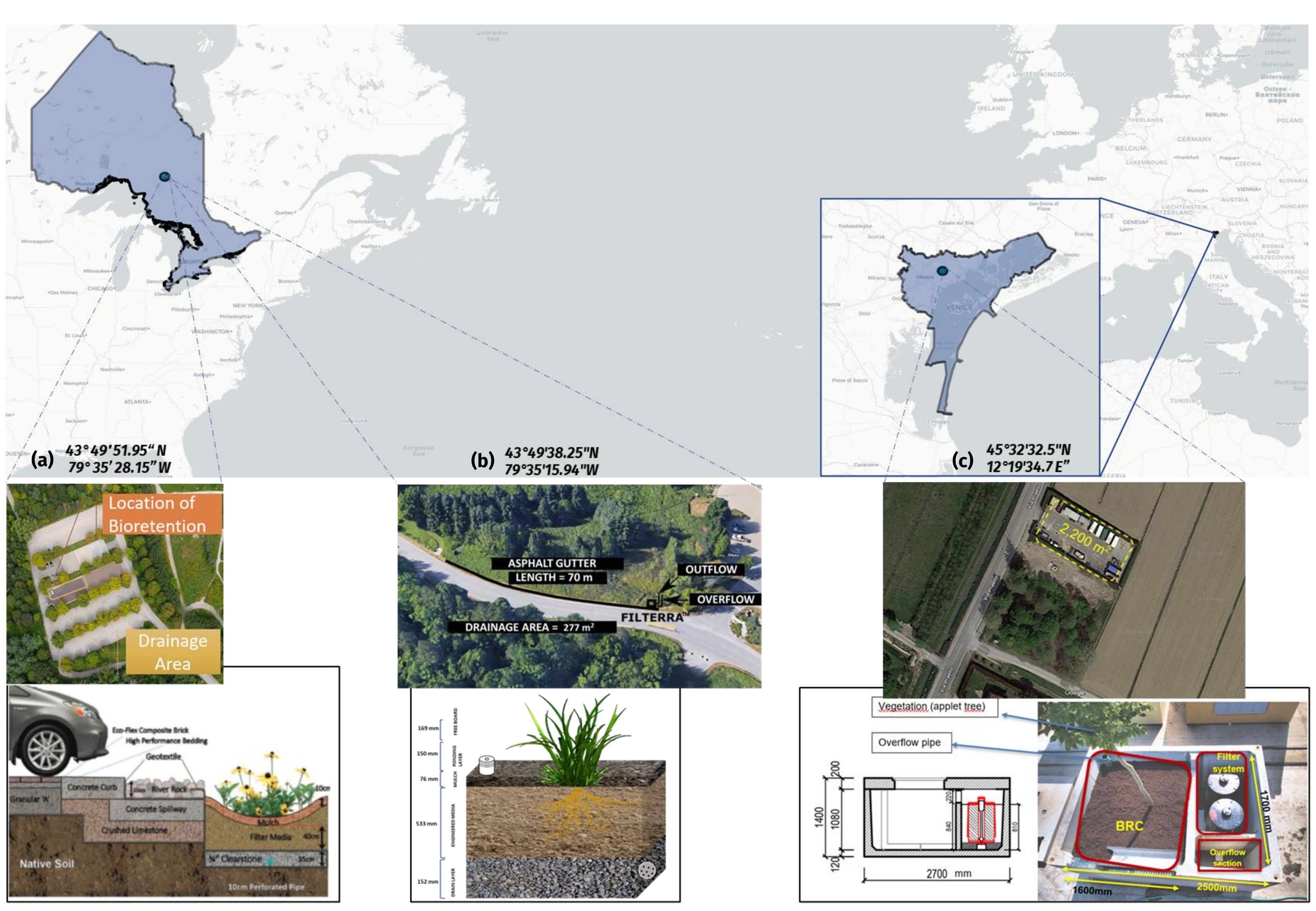
The main objective of this study is to assess the effectiveness of BRC in the management of urban stormwater runoff.

Specifically, the study aims to:

- Evaluate the relationship between site-scale performance of BRC and their effect on hydrological processes at the catchment scale.
- Evaluate the impact of BRC placement density and footprint on catchment scale hydrologic responses.
- Evaluate the potential of a calibrated BRC modelling approach to reliably predicted TSS reduction from comparable BRC systems under diverse land use and climatic conditions.

Material and Methods

Site and Bioretention Cell Description



(a)

Site Description

- Location: Kortright Center, Vaughan Ontario, Canada
- drainage area surface: 265 m2
- Land use category: Impermeable parking lot

BRC Description

- Surface area: 30 m2
- Mulch layer: 7.5 cm that covers of hardwood mulch
- Media layer: 40 cm layer of sandy loam filter media.
- Drainage layer: a perforated pipelines with a 10 cm diameter that are positioned on the surface of the native soil.
- The ratio of BRC surface area to drainage area: around 11%.
- Non-exfiltration

(b)

Site Description

- Location: Kortright Center, Vaughan, Ontario, Canada.
- drainage area surface: around 277 m2
- Land use category: Impermeable Road

BRC Description

- Surface area: 1.4 m2
- Mulch layer: 7 cm that covers of hardwood mulch
- Media layer: 53 cm layer of engineered filter media.
- Drainage layer: a perforated pipelines with a 15 cm diameter wrapped with washed gravels.
- The ratio of BRC surface area to drainage area: < 1%.
- Non-exfiltration

(c)

Site Description

- Location: Eco centro Marghera, Venice, Veneto, Italy
- drainage area surface: 2200 m2
- Land use category: collection of wastes .

BRC Description

- Surface are: 2.7 m2
- Mulch layer: 7.5-10 cm that covers of hardwood mulch
- Media layer: 40-60 cm layer of engineered filter media.
- Drainage layer: a perforated pipelines with a 15 cm diameter wrapped with washed gravels.
- The ratio of BRC surface area to drainage area: < 1%.
- Non-exfiltration

Precipitation Regimes

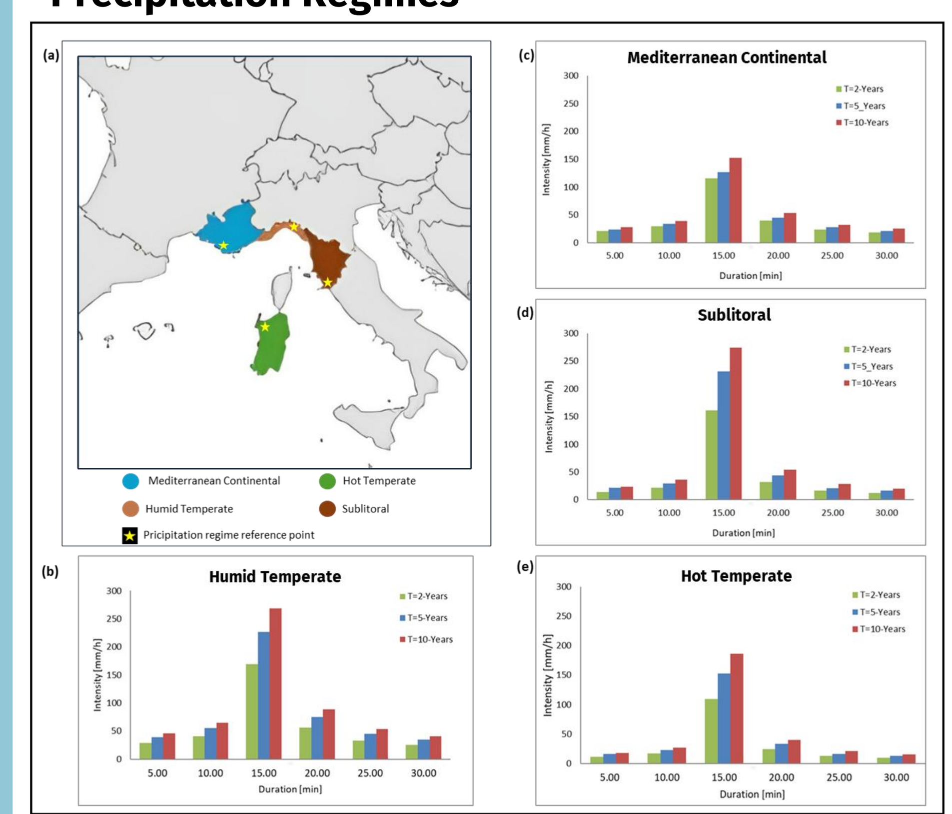
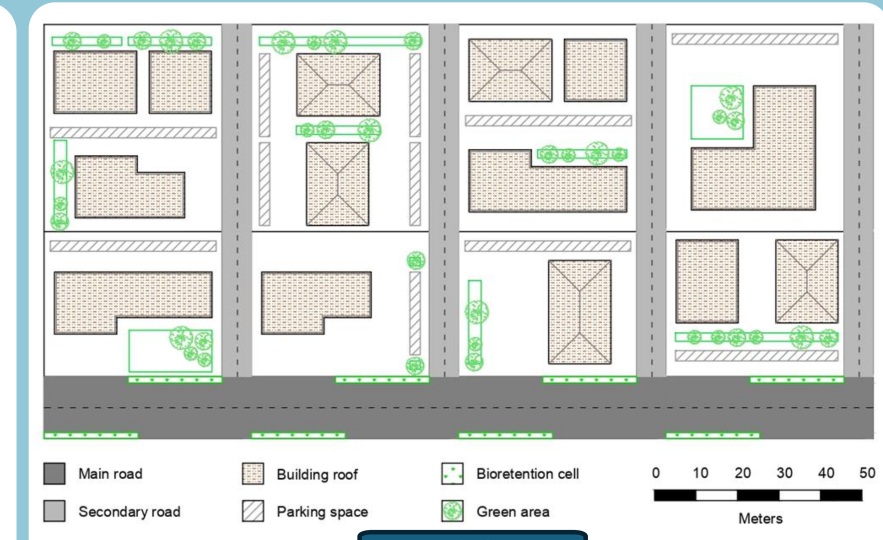


Figure 2: (a) Overview of the investigated area with different precipitation regime; and the corresponding synthetic hyetographs fat different return period:(b) Humid Temperate (HuT), (c) Mediterranean Continental (MeC), (d) Sublitoral (Sub) and (e) Hot Temperate (HoT) . The hyetographs are evaluated based on the regional studies on the extreme precipitations of Liguria, France, Tuscany , and Sardinia [4].

SCAN ME



(d)

Site Description

- 2 ha urban catchment area simplified into streets (0.54 ha, 100% impervious) and residential (1.46 ha, imperviousness ranging from 30 to 90%) sub-catchments.
- Drainage network with 13 junctions and 12 conduits.

BRC Description

- Ponding zone: 30 cm
- Media layer: 70 cm layer of sandy-loam filter media. .
- The ratio of BRC surface area to drainage area: 5%,10%,15%, and 20%.
- Full-exfiltration

Data Used

Vaughan, Ontario BRC

- The periods of monitoring were 2013–2014 and 2017–2018.
- 5-minute rainfall data, inflow was initially monitored via 3-L tipping bucket and a 60-degree Parshall flume with bubbler flow meter recording continuously flow every minute.
- Outflow was monitored using an HDPE pipe guided to a monitoring hut with a 3-L tipping bucket
- Automated samplers collected inflow and outflow water quality samples proportionally to flow.

Venice, Veneto Filterra

- At this location, a monitoring station installation and setup are under proceeding. Water quality parameters will be monitored using an installed multiparametric sensor

Vaughan, Ontario Filterra

- The periods of monitoring were from mid-June to the first week of November in 2017, and May to November in 2018.
- 5-minute rainfall data, inflow was monitored using an area-velocity with 1 min resolution.
- Outflow was measured with a 22.5-degree V-notch weir box with 1 min resolution.
- Overflow was captured and measured with a calibrated orifice flow monitoring device downstream with 1 min resolution.
- Automated samplers collected inflow and outflow water quality samples proportionally to flow.

Non-specific Urban Catchment

- 4 degrees of imperviousness (30, 45, 75, 90%)
- 4 synthetic precipitation regime with 3 return periods (2, 5, 10 years)
- BRC settings:
  - 4 BRC footprint area (5%,10%, 15%, 20%)
  - 2 BRC placement: (All Roads and Main Roads)

Modeling

In this research EPA's Storm Water Management Model (SWMM) is used. SWMM is a physically based semi-distributed and discrete-time simulation model. The BRC sites will be simulated employing the EPA SWMM 5.2 model coupled with R and QGIS.

QGIS R EPA SWMM

Results Obtained

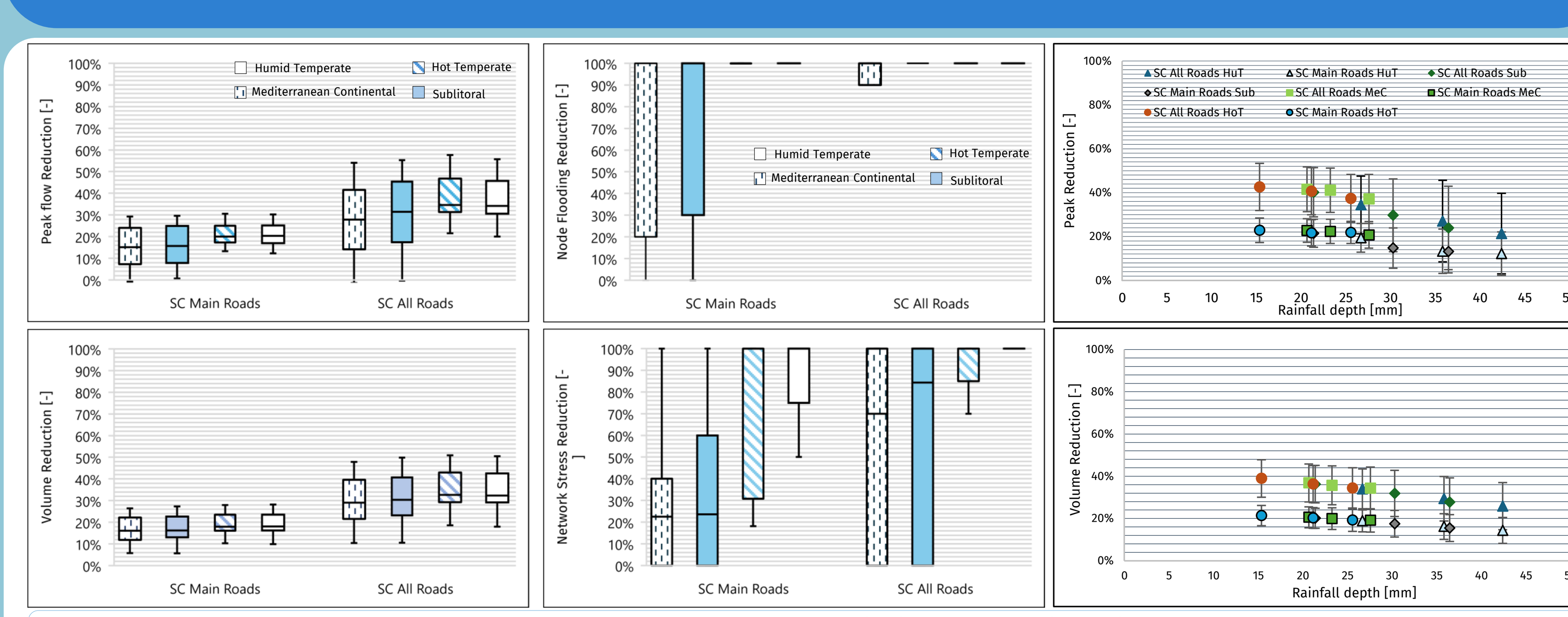


Figure 3. Results obtained for the non-specific urban catchment. Box plot of Hydrologic (left) and Hydraulic (middle) metrics with respect to the scenarios of Bioretention Cell placement. Scatter plots depicting mean Volume Reduction and Peak Reduction in relation to rainfall depth (Right).

Expected Results

- Comprehending the connection between site scale BRC performance and catchment scale finding suitable hydrologic measures that accurately measure the performance of BRCs at both site and catchment scales. This would offer measures to establish a connection between site-scale monitoring and catchment scale responses.
- Understanding the flow patterns are affected by changes in the design configurations (footprint and density) of BRC within an urban catchment. This might provide valuable information to develop retrofit designs.
- Development of a calibrated and validated SWMM model using monitoring data from one site and proven to reliably forecast water quality benefits of new BRC placements without monitoring design accounting for variations in factors like rainfall and land use. This would advance the utility of models for retrofit planning.

Contact

Shaahin.nazarpour.tameh@edu.unige.it
Ilaria.gnecco@unige.it
Anna.palla@unige.it

Università di Genova · SWI group · Carleton University · PON Ricerca e Innovazione

Reference

1. Lisenbee, W. A., Hathaway, J. M., Burns, M. J., Fletcher, T. D. (2021). Modeling bioretention stormwater systems: Current models and future research needs. Environmental Modelling & Software, 144, 105146.
2. Nazarpour, S., Gnecco, I., Palla, A. (2023). Evaluating the Effectiveness of Bioretention Cells for Urban Stormwater Management: A Systematic Review. Water 15(5), 913.
3. Palla, A., Gnecco, I. (2022). On the Effectiveness of Domestic Rainwater Harvesting Systems to Support Urban Flood Resilience. Water Resources Management 36, 5897–5914.
4. Palla, A., Gnecco, I. (2021). The web-GIS platform TRIG Eau to assess the urban flood mitigation by domestic rainwater harvesting systems in two residential settlements in Italy. Sustainability, 13 (13), 7241.