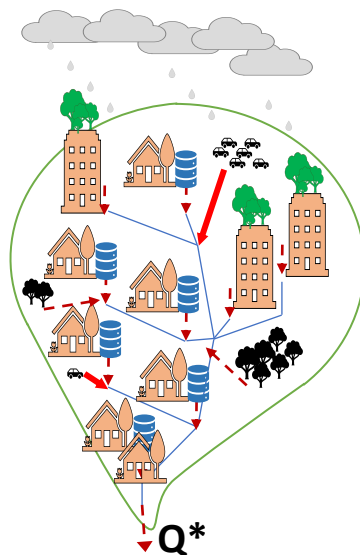
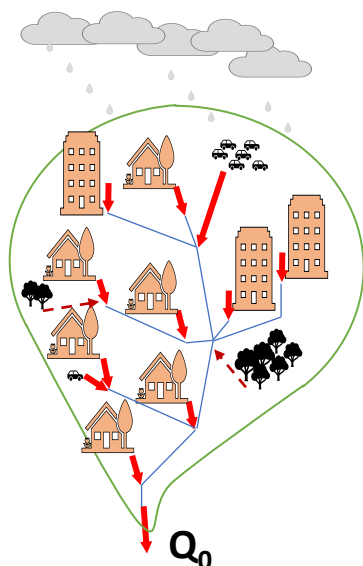


*Unaltered
conditions*



What if we install
BLUE-GREEN
solutions
on ALL roofs in a city?



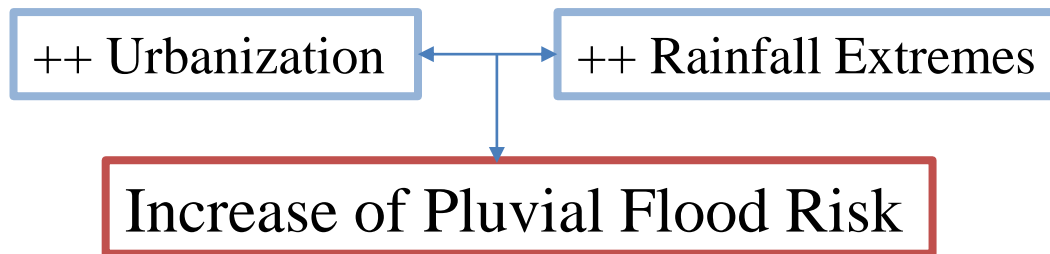
Installation of blue-green solutions at large scale to mitigate pluvial floods

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Pluvial flood mitigation

The growth of urbanization and the intensification of extreme rainfall events, that characterized the last century, are leading to an increase of pluvial floods, which are becoming a significant problem in many cities.



Blue-Green Solutions for flood mitigation :

- ❖ Permeable pavements
- ❖ Water Plaza
- ❖ Rain Water Harvesting Systems
- ❖ Green Roofs
- ❖



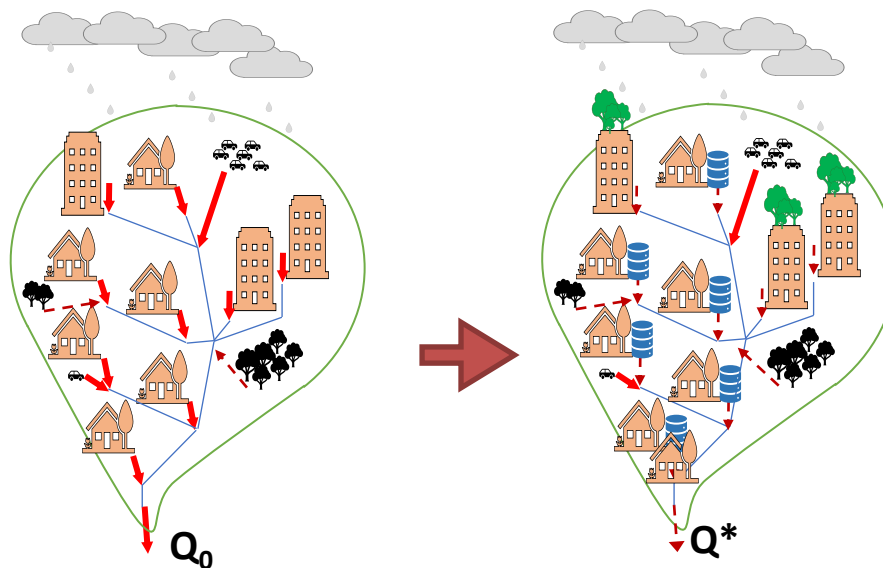
Among the different solutions developed to mitigate flood risk in urban areas, green roofs and rainwater harvesting systems have been deeply investigated to reduce the runoff contribution generated from rooftops.

Problem

These tools have been studied **at small scale**, analysing the flood reduction that can be achieved from one single building or in a small neighbourhood.

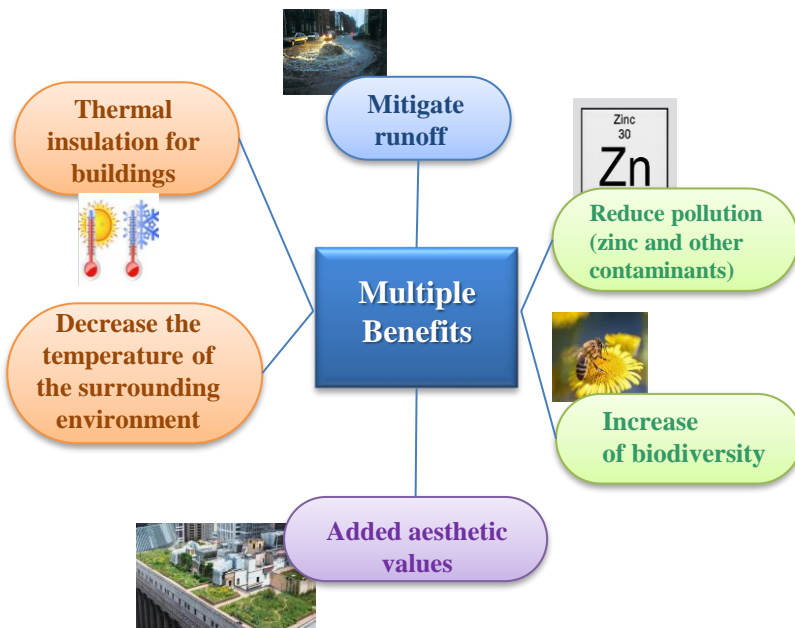


What is potential impact of the installation of green roofs and rainwater harvesting systems **on all the rooftops of a city?**



What happens if we install green roofs (🌳) on all flat roofs (🏠) and rainwater harvesting systems (💧) on sloped roofs (🏠)?

Green roofs



Green Roofs can be installed only on **flat roofs**, and they often require **additional structures** to ensure the **building stability**

Both **EXTENSIVE** and **INTENSIVE** Green Roof categories have been evaluated

Rain Water Harvesting systems

ADVANTAGES

RWH systems can be easily installed in an urban context to **mitigate rainfall extremes**.

Collected water, if properly treated, can be **reused for different domestic purposes**.

RWH can be installed on **any type of roof**.

DISADVANTAGES

RWH requires **large space to locate the water tanks**



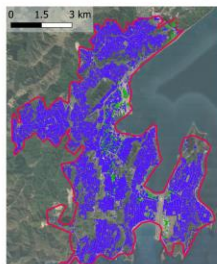
Example of Rainwater tank from
http://www.navinaquatech.com/rain_water_harvesting.php

Study Cases

Nine cities from 5 different countries (Canada, Haiti, United Kingdom, Italy and New Zealand), representing different climatological and geomorphological characteristics, were investigated.

Flat (green) and sloped (blue) roofs, highlighted in the maps, have been identified through an automated process, starting from the Digital Surface Models available at high resolution ($\sim 1\text{m} \times 1\text{m}$).

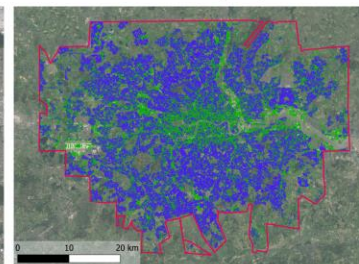
Wellington (L8)



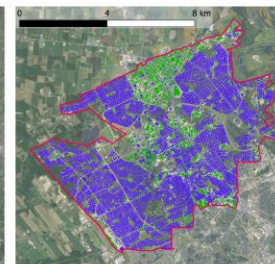
Vancouver (L9)



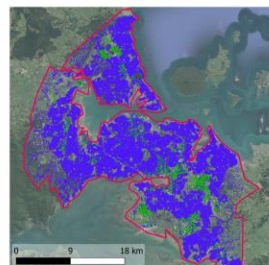
London (L1)



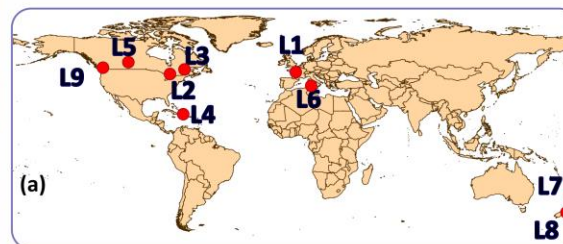
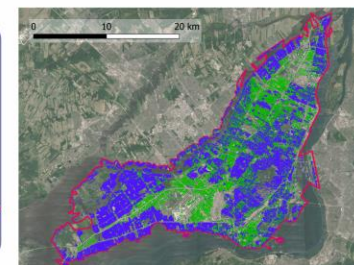
Waterloo (L2)



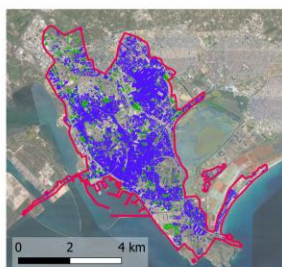
Auckland (L7)



Montreal (L3)



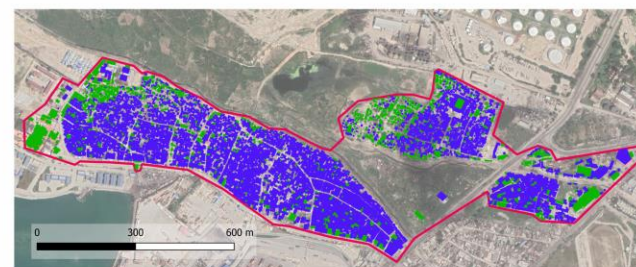
Cagliari (L6)



Airdrie (L5)



Port au Prince (L4)



From "Blue-green solutions for urban flood mitigation: a multi-city large scale analysis", Scientific Reports, under review.

Methodology

The behaviour of **Green roofs (GR)** and **Rainwater Harvesting (RWH)** has been estimated with a conceptual lumped ecohydrological model EHSM^{1*} and the mass conservation.

Rainfall and temperature time series have been used as climatological input to **derive the discharge reduction** for different scenarios (Extensive and Intensive GR, RWH and coupled systems GR-RWH).

A **unitary cost** of :

- 100 € /m² for extensive GR
- 250 € /m² for intensive GR
- 170 €/m³ for RWH systems

was assumed to estimate the total cost.

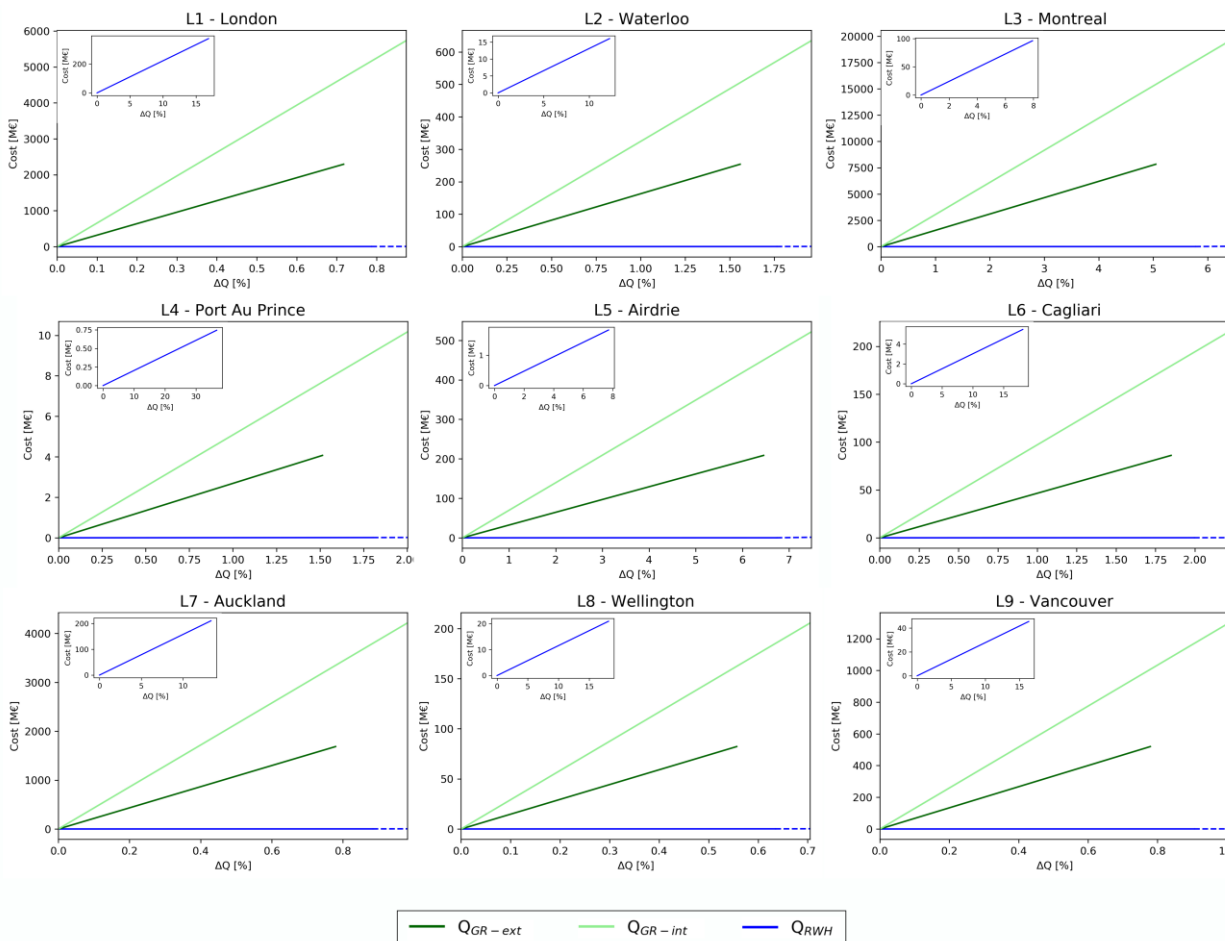
Maximum discharge reduction and total costs have been estimated in correspondence of an extreme rainfall event, **equal to the 95% quantile** of the non-zero rainfall time series (**Results (I)**).

Potential discharge reduction variability for extreme rainfall events, considering **events with rainfall intensity above the 95% quantile** of the non-zero rainfall time series have been investigated in relation to the discharge in unaltered conditions (**Results (II)**)

^{1*}Viola, F., Pumo, D. & Noto, L. V. EHSM: a conceptual ecohydrological model for daily streamflow simulation. *Hydrological Processes* **28**, 3361-3372, doi:10.1002/hyp.9876 (2014)

Results (I)

The figure highlights the maximum potential discharge reduction ΔQ , as a percentage of the unaltered runoff, and the total cost (in M€) required for the installation of the 3 investigated scenarios.

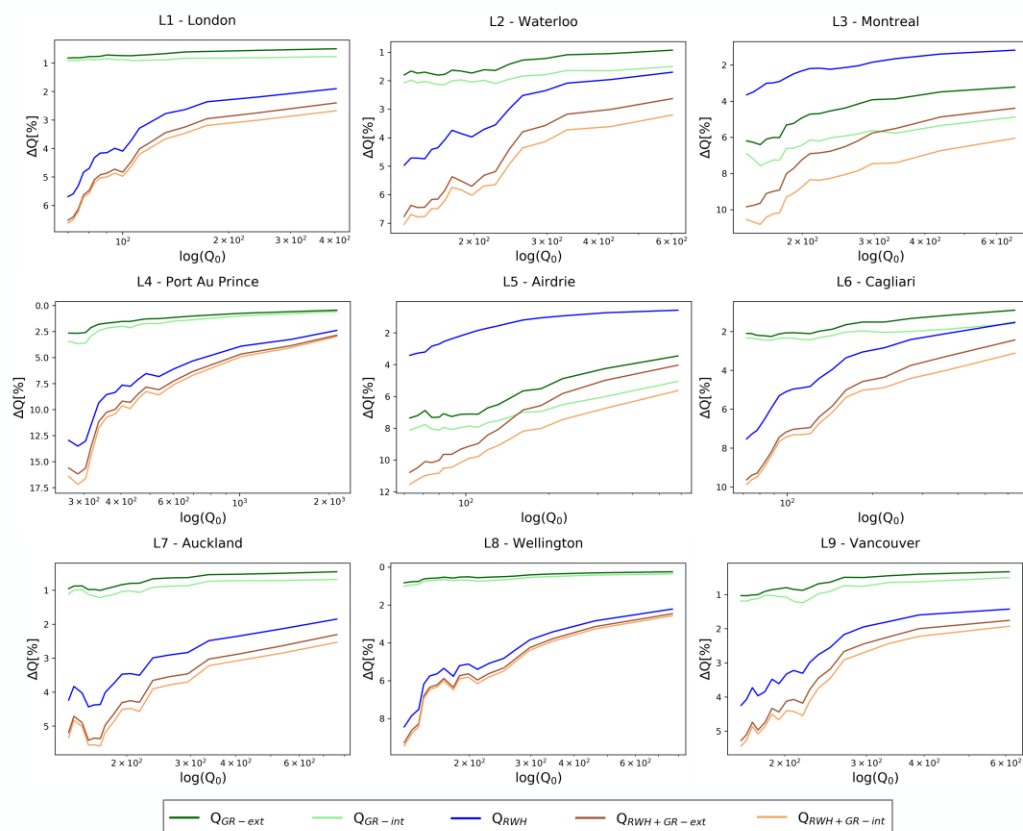


Due to the **high percentage of sloped roofs** in most of the investigated locations, the cost-efficiency analysis highlights that the large-scale installation of **rainwater harvesting tanks** enables to achieve **higher mitigation capacity** than green roofs at **lower cost**.

From "Blue-green solutions for urban flood mitigation: a multi-city large scale analysis", Scientific Reports, under review.

Results (II)

The best achievable performance is given by the **coupled system of rainwater harvesting tanks and intensive green roofs**: for extreme rainfall events this solution guarantees a discharge reduction up to 10% in most of the cities.



As Q_0 increases (corresponding to more intense rainfall events), a **general worsening of the potential efficiency** of blue-green solutions is observable, being almost negligible for very intense extremes (still above 2% for the coupled system RWH-GRint)

From "Blue-green solutions for urban flood mitigation: a multi-city large scale analysis", Scientific Reports, under review.

Summary and Conclusions

- ✓ Roof slope distribution in cities strongly influences the potential mitigation capacity of the installation of Nature-Based Solution at large urban scale.
- ✓ Assuming to install Green roofs on flat roofs and rainwater harvesting systems on sloped ones, rainwater harvesting tanks enables to achieve **higher mitigation capacity** than green roofs **at lower cost**.
- ✓ Green roofs, however, present many additional benefits (such as biodiversity contribution, thermal insulation for buildings, pollution reduction and increase of aesthetic added value) that need to be evaluated by urban planners and policy makers.
- ✓ The best achievable performance is given by the coupled system of rainwater harvesting tanks and intensive green roofs: for extreme rainfall events this solution guarantees a discharge reduction up to 10% in most of the cities.