Università di Genova
DICCA DIPARTIMENTO DI INGEGNERIA CIVILE, CHIMICA E AMBIENTALE

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A case study of a rainwater harvesting system for the irrigation of green areas within an urban reconversion project

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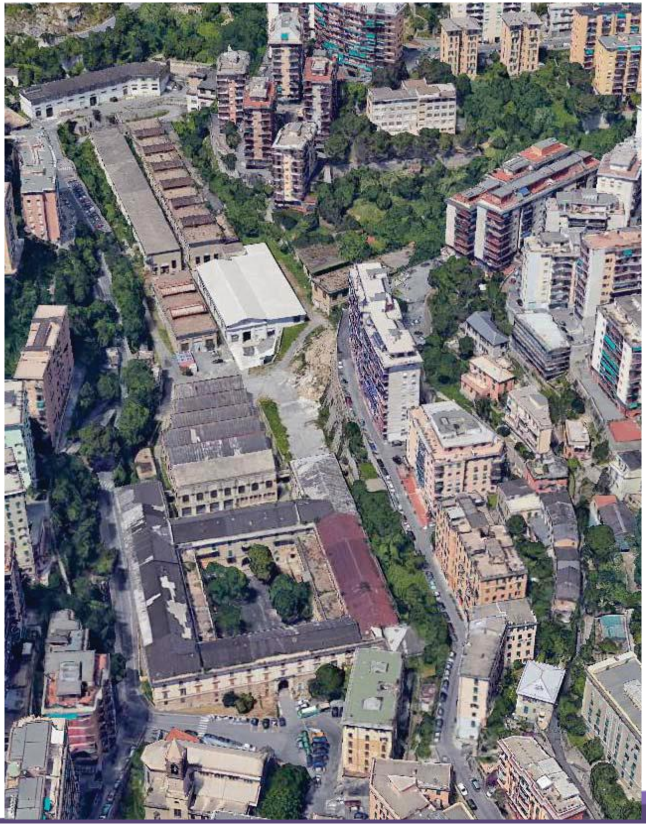
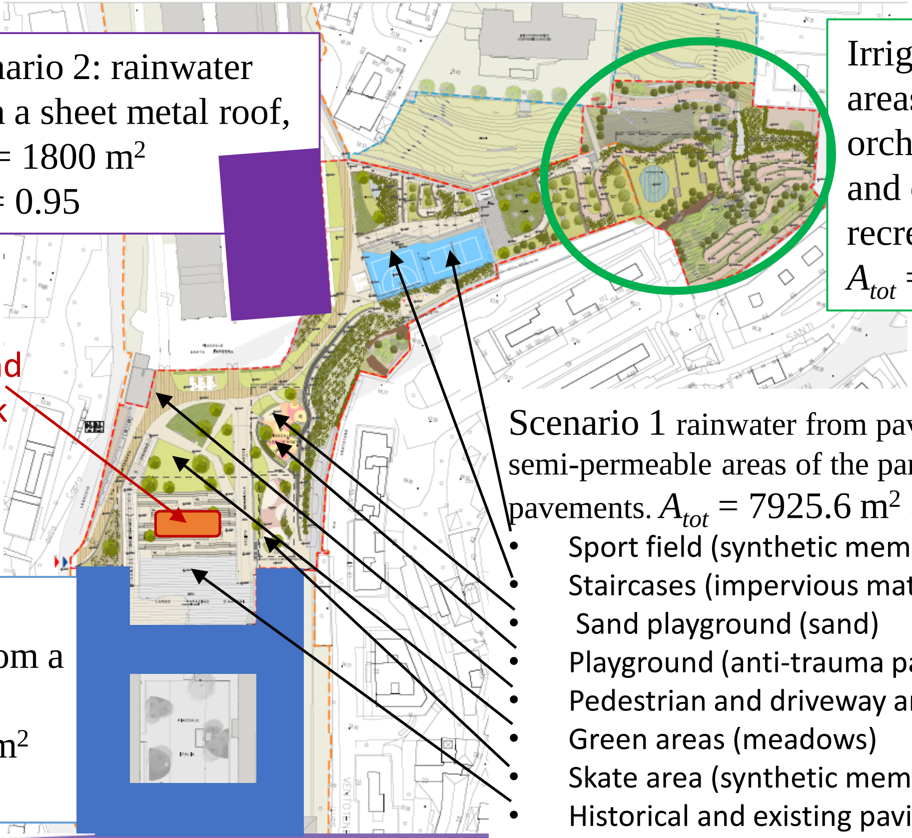
Design of a Rain Water Harvesting (RWH) system for landscape irrigation of public areas

Former military area located in the town of Genova (Italy) before reconversion



Three rainwater collection scenarios were investigated



Scenario 2: rainwater from a sheet metal roof, A_{tot} = 1800 m^2 ϕ_{eq} = 0.95

Irrigated green areas for picnic, orchards, dog areas and other recreational uses. A_{tot} = 3600 m^2

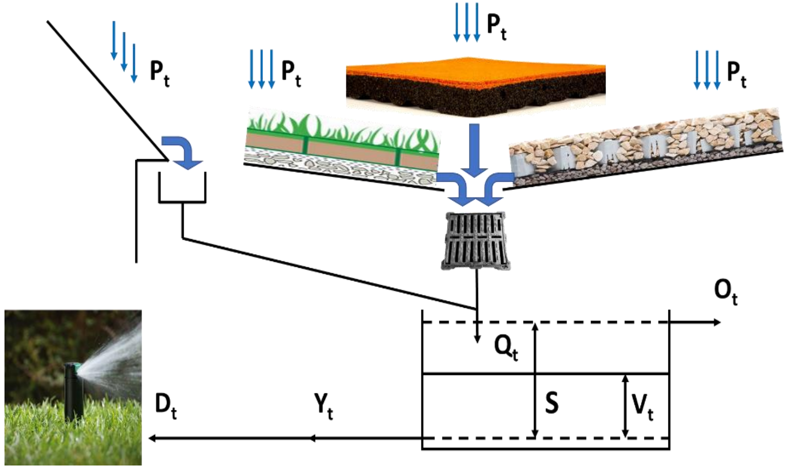
Underground storage tank

Scenario 3: rainwater from a brick roof, A_{tot} = 4960 m^2 ϕ_{eq} = 0.85

Scenario 1 rainwater from paved portions, green or semi-permeable areas of the park, including porous pavements. A_{tot} = 7925.6 m^2 and ϕ_{eq} = 0.4

- Sport field (synthetic membrane)
- Staircases (impervious material)
- Sand playground (sand)
- Playground (anti-trauma paving)
- Pedestrian and driveway area paving (resin gravel)
- Green areas (meadows)
- Skate area (synthetic membrane)
- Historical and existing paving (stone)

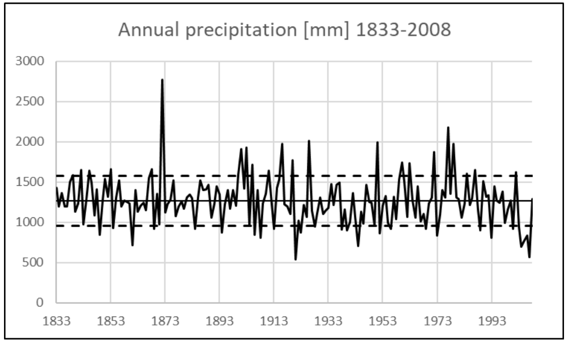
Schematics of the RWH system



$$Q_t = P_t \cdot \phi \cdot A$$

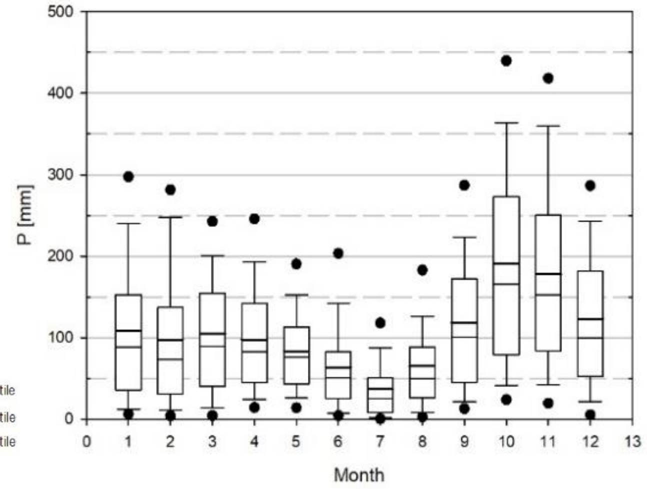
INPUT

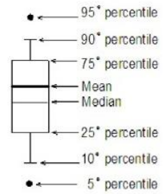
Quasi bi-centennial daily rainfall record as observed at the meteorological station of Genova Università



P_t is the precipitation amount;
A extension of a generic collection area;
ϕ runoff coefficient of a generic collection area;
Q_t the rainwater inflow to the storage tank;
S the storage capacity of the system;
V_t the rainwater volume stored in the tank;
Y_t the released volume;
O_t is the overflow volume;
D_t the water demand.

Seasonal variability of monthly precipitation





Heavy rainfall in the autumn season and scarce rainfall in the summer season.

The performance of the RWH system is assessed by using a behavioral model based on a daily mass balance for the tank:

$$V_t = Q_t + V_{t-1} - Y_t - O_t$$

Yield After Spillage (YAS) algorithm as suggested in the literature for conditions that are similar to those of the present study

$$Y_t = \min \begin{cases} D_t \\ V_{t-1} \end{cases} \qquad V_t = \min \begin{cases} V_{t-1} + Q_t - Y_t \\ S - Y_t \end{cases}$$

OUTPUT

The total daily demand for irrigation D_t is therefore given by:

$$D_t = I_{t,meadow} \cdot A_{meadow} + I_{t,shrubs} \cdot A_{shrubs} + I_{t,trees} \cdot A_{trees}$$

where I_t and A the water supplied through the irrigation system and the surface areas of the irrigated portions covered with meadows, shrubs and trees, respectively.

Soil water depletion algorithm

For each type of vegetation that is subject to irrigation (meadows, shrubs, trees), the actual soil water content $WHC_{eff,t}$ is calculated based on the daily water need f, with the following algorithm:

If $P_t > WHC - (WHC_{eff,t-1} - f + I_{t-1})$

$$WHC_{eff,t} = WHC$$

else

$$WHC_{eff,t} = WHC_{eff,t-1} + P_t - f + I_{t-1}$$

Excess precipitation, when larger than the soil Water Holding Capacity (WHC), either percolates due to gravity until the deep soil and is drained away or becomes surface runoff and is collected and stored in the tank.

I_t is obtained as a function of the actual soil water content $WHC_{eff,t}$ according to the following criteria:

If $WHC_{eff,t} \leq 0.8 \cdot WHC$

$$I_t = f$$

else

$$I_t = 0$$

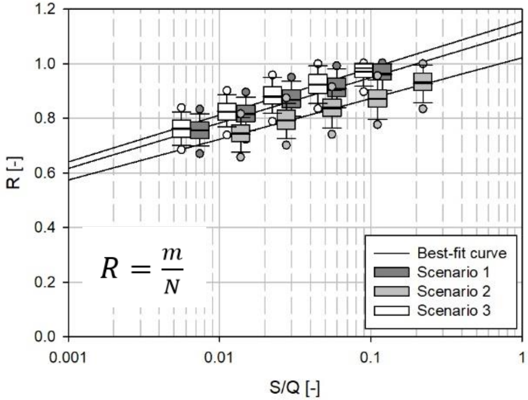
- irrigation is not activated if it rains at least the daily water need or, in dry days, the soil water content is at least 80% of the WHC;
- irrigation is always activated when the soil water content drops below the threshold of 80% of the WHC;
- the WHC of the soil is recovered only after sufficiently large precipitation events but not from irrigation, which is used to ensure that only the water need of vegetation is fulfilled.

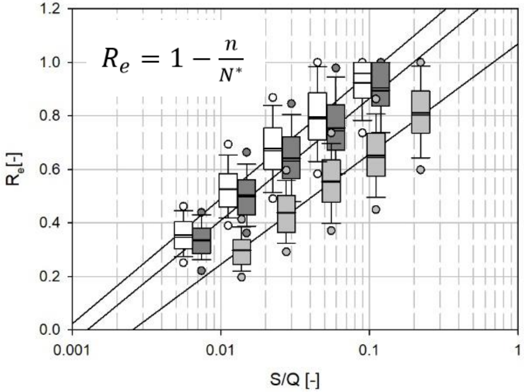
RESULTS

- fraction of time when storage is not empty (R) and when the demand is fully met (R_e)

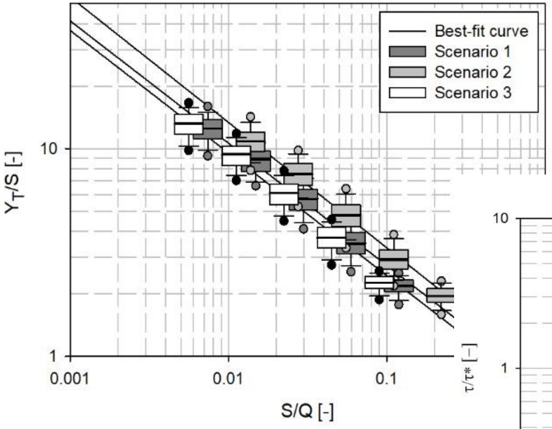
m num. of days when the tank is not empty, N total num. of days, n num. of days when the stored volume does not fully meet the demand and N* is the number of days when $D_t > 0$

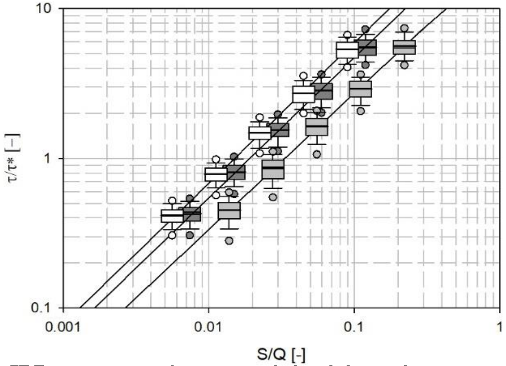
Non-dimensional temporal and volumetric reliability indexes as a function of the storage fraction (S/Q)



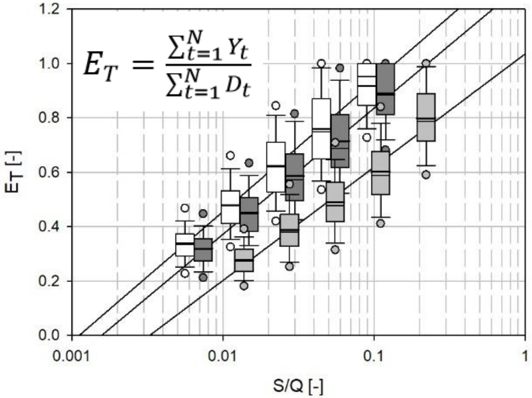


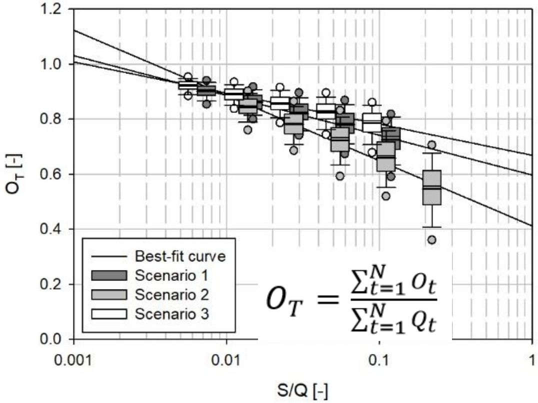
Various tank sizes are investigated (S = 30 - 480 m^3)





- efficiency (E_T) and overflow ratio (O_T)





The economic benefit of a RWH system is provided by the annual usage volume per unit of tank capacity (U), where Y_T is the annual released volume, while to check the quality of the collected water the detention time (τ) is calculated.

CONCLUSIONS

- Scenario 3, the one collecting rainwater from the brick roof with a tank size of 120 m^3 is the most efficient scenario. It is characterized by the normalized detention time close to the reference value assumed in this work (three days);
- Scenario 1, where the drainage from ground surfaces is collected, exhibits very similar performance but a more complex drainage network below the various ground surfaces contributing rainwater to the storage tank is required;
- Scenario 2, with the rainwater collected from the sheet metal roof is less performant due to the reduced size of the collecting surface and would require doubling the size of the storage tank to achieve similar efficiency values than in the other two scenarios;
- In all cases, the overflow ratio is quite high, reflecting the large portion of rainwater that is collected but not used for irrigation due to the scarce synchronization between the availability and the demand. This indicates that further usages of the collected rainwater would be compatible with the demand for irrigation, e.g., the supply of toilet flushing in the public or nearby areas.

Acknowledgements

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