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Modelling stormwater reuse scenarios for green roof irrigation using URBIS

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SUMMARY

In this study eight different strategies for irrigation a green roof involving water reuse from a retention basin and drinking water were compared using the open software URBIS. The results allow to design a system minimizing the risk of drought in the green roof substrate and the required volume of drinking water.

KEYWORDS

Green roofs, Irrigation, Modelling, Water reuse.

INTRODUCTION

Green roofs have been seen as a promising solution to manage stormwater and reduce heat island effect coping with increasing imperviousness in urban area. Using them for efficient urban stormwater control require maximizing detention, and evapotranspiration. If the first process mainly depends on the roof structure (size, substrate material, etc.), the later one strongly depends on the state of vegetation and on the available water content in the substrate. Indeed, actual evapotranspiration diminishes and may be significantly reduced compared to maximum potential evapotranspiration if the water content in the substrate (and in possible additional underlying storage) is lower than field capacity. In the worst case, i.e. if the water content is below the wilting point, there is water stress and evapotranspiration will be stopped and can lead to permanent damage to the vegetation. Irrigation of green roofs, whilst it lead to an increase of water consumption and can increase the runoff (Hill et al., 2017), can be beneficial on a long-term to maximize evapotranspiration (Van Mechelen et al., 2015) and can be achieved though water reuse (Hardin, 2006; Hardin et al., 2012).

The objective of this work is to evaluate and compare the potential of eight different irrigation scenarios for a green roof case study, based on simulations with the URBIS free software (see Sandoval et al., 2019). Especially: *i)* to implement irrigation strategies, *ii)* to quantify the impact of irrigation strategies on retention metrics, and *iii)* to evaluate the use of irrigation based on limited water resources.

METHODS

Case study and scenarios

A simple case study with a 500 m^2 green roof is proposed, consisting in 60 mm of substrate (18 mm of water) with 150 mm of storage with regulated discharge of 1 L/s/ha (typical standard design that could be used in Lyon, France) and a 100 m^2 open stormwater basin. The basin includes a 1000 mm deep storage (950 mm of water) layer with a regulated discharge of 1 L/s/ha set at 500 mm from the bottom of the basin to allow permanent storage.

The input data consists in a 20-year timeseries (from 1992 to 2002) of recorded precipitation and modelled evapotranspiration for the city of Lyon, France with a 6-minute timestep.

Eight different irrigation scenarios were created, as detailed in Table 1. In addition to the type of inflow (precipitation, water reuse or drinking water), the scenarios also differ in terms of irrigation triggering thresholds and target values. In the scenario 8 the basin collects water from an upstream impervious area of 500 m^2.

Irrigation strategy
In the model the irrigation is based on an evaluation made at 00:00 every day quantifying the irrigation need based on a trigger and a target value. Effective irrigation depends both on the pump discharge and available water. Water reuse is prioritized over drinking water.

Table 1.1 The different strategies of irrigation implemented. *WP* is the wilting point, *FC* is the field capacity, and *HS* is the hydric stress ($HS = WP + 0.4 \times (FC - WP)$).

	S1	S2	S3	S4	S5	S6	S7	S8
Drinking water	X	-	-	X	-	X	X	-
Retention basin	X	X	-	X	X	X	-	X
Upstream area	-	-	-	-	-	-	-	X
Trigger threshold	HS	HS	-	HS	HS	$\frac{HS+WP}{2}$	HS	HS
Target threshold	FC	FC	-	$\frac{HS+FC}{2}$	$\frac{HS+FC}{2}$	$\frac{HS+FC}{2}$	FC	FC

Performance indicators
In order to evaluate and compare the scenarios, the following aspects are considered: *i)* drinking water consumption, *ii)* distribution of periods under hydric stress, *iii)* probability of a hydric stress event to last more than 1 week.

RESULTS AND DISCUSSION

An example period from January to December 2003 is shown in Figure 1. On the top the different inflow into the green roof are presented. Only the scenario with drinking water (S1) can provide inflow under all conditions. The middle plot shows the water level in the substrate with irrigation (S1), irrigation based only on stormwater reuse (S2) and without irrigation (S3). The bottom plot shows the water available to be reused for irrigation. On the top left the cumulative distribution of the duration or period of hydric stress for all scenario and on the bottom the nature of the inflow for all scenarios.

The results presented in Figure 1 show that, for the climatic conditions of Lyon, France, the risk of a long duration (> 1 week) of hydric stress is high if no irrigation measure is taken. Moreover, according to climate change projections (future time series based on IPCC RCP8.5 hypotheses, results not shown here), the risk of drought might increase in this region. The scenarios with the use of drinking water (S1, S4, S6 and S7) ensure a short duration under hydric stress; however such a measure is likely to be restricted in the future due to limited drinking water during drought periods (several legal restrictions of water use in summer periods in the region of Lyon have been in force since 2005, see Sauquet et al., 2018).

On the left bottom figure, for the scenarios S1 and S2, the basin is dry from mid-May. Consequently, it is not possible to irrigate the roof with S2 while it is still feasible with S1. In this period, lowering the irrigation trigger and target did not lead to a significantly slower decrease of the stormwater resources. Without irrigation (S3), 40% of the period of hydric stress might last more than 1 week. Using drinking water, it is possible to completely prevent it. Approaches with only stormwater reuse from the storage basin can lower the risk of long hydric stress to less than 15%. A more advanced scenario based on a basin collecting the discharge from the roof or a surrounding, such as S8, has the potential to decrease the risk significantly to less than 1 % of the hydric stress periods. A draw back for this strategy is the risk of overflow increasing in the basin, the height of the discharge limiter needs to be balanced between the risk of long hydric stress and overflow. Scenarios based on irrigation trigger and target adjustment allow to lower the drinking water consumption and let the collected stormwater to last longer. Except S8, the different scenarios did not lead to an increase of overflow. The scenarios S2, S4 and S6 lead to a similar volume of drained water while scenarios such as S1 or S2 with a target at field capacity lead to regulated volume 10 to 20% higher.

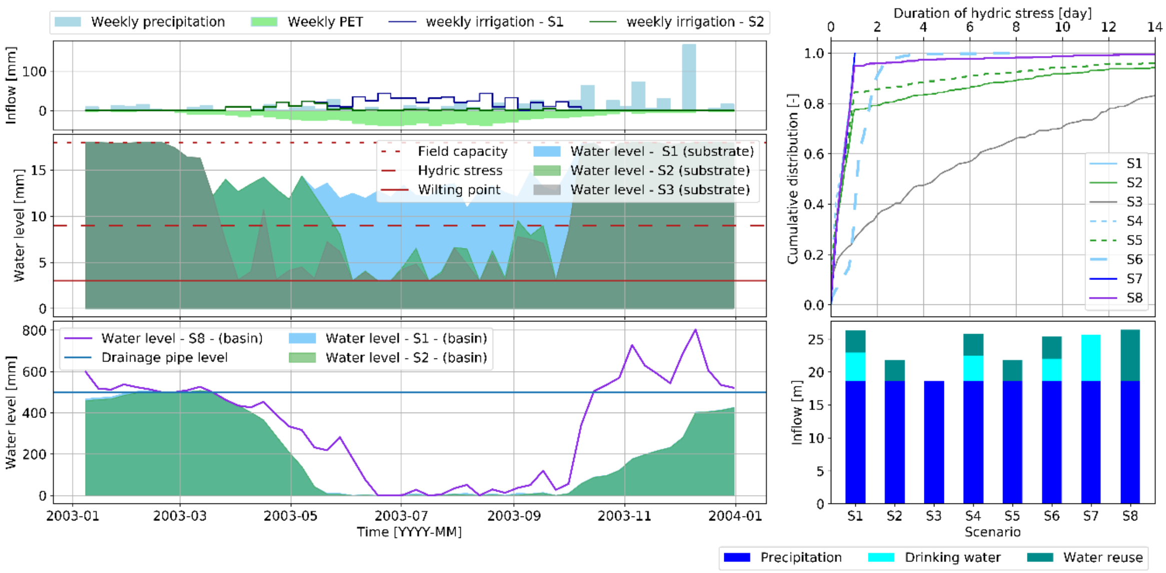

Figure 1.1 Different scenarios of irrigation simulated with a 20-year long time series. On the left: simulation of year 2003. On the right: distribution of periods of hydric stress (top), and detail on the origin of irrigation water (bottom).

CONCLUSIONS

Different scenarios of green roof irrigation based on drinking water or stormwater reuse were implemented in the software URBIS. Irrigation appears as necessary to ensure the maximum evapotranspiration and maintain the vegetation. Strategies based on drinking water allow to mitigate the risk of long hydric stress periods under the hypothesis of water constantly available without restriction. Storing stormwater appears as an efficient alternative solution for this purpose. Further studies are needed to elaborate optimal strategies depending on green roofs specific surface and climate conditions.

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