Projet financé

SELF TRAINING PROJECT : page 1

PROJET D'AUTOFORMATON : en préparation

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Objectives

The two main objectives of this URBIS self-training project are the following ones:

- Simulate and compare different stormwater management scenarios for a simple but real case.
- Discover all the functionalities, techniques, and parameters of URBIS, and learn how to use them to simulate a project.

This self-training project was initially prepared for INSA Lyon MSc students. In this version, examples of results are given to help the reader. All tested scenarios in the project are not necessarily the most recommended ones in reality: they only are proposed here to lead the user to test and explore various possibilities of the URBIS software.

Hypotheses and simulation

Scenarios and hypotheses used in this project are inspired from a real case study: a residential building in the city of Lyon, France (Figure 1).

Figure 1: Residential building in Lyon, France used as a test case for the self-training project.

Rainfall, evaporation, evapotranspiration, and infiltration are considered as spatially uniform over the project area. For simplicity, all surfaces are described in the model only by their areas, regardless of their exact detailed 3D geometry.

The simulation conditions are simplified in order to shorten the calculations: rainfall and evapotranspiration data are provided on a two-year basis: use the file `Lyon_2001_2002.txt` which contains the precipitation and potential evapotranspiration for Lyon in the years 2001 and 2002 at a 6-minute time step. When a parameter value is not specified in the simulation steps presented in the following sections, default values proposed by URBIS are used for the simulation parameters. The exact set of parameters used by the authors will be detailed with the simulation results.

The user is free to use any other meteorological data series to evaluate other scenarios, as well as to change the values of the different parameters to analyse how they may affect the modelling results.

The results given by the authors are only indicative and the simulation parameters are flexible. The aim is to understand how to work with the URBIS software and to check the coherence between the simulation hypotheses and the modelling results. Of course, this self-training project cannot replace a full training course.

Step 1

Urban areas include mainly impervious constructed infrastructures such as roofs, roads, sidewalks, parking lots, etc., covered with watertight materials (asphalt, concrete, bricks, etc.) which generate runoff in cities and can end up with damages such as flood.

The first step illustrated below is the worst case scenario: the urban residential building (Figure 1) is assumed to be equipped with a flat roof and a completely impervious inner courtyard, with the dimensions specified in Figure 2.

Run the simulation with this initial scenario during the period 2001-2002 and look at the global water balance.

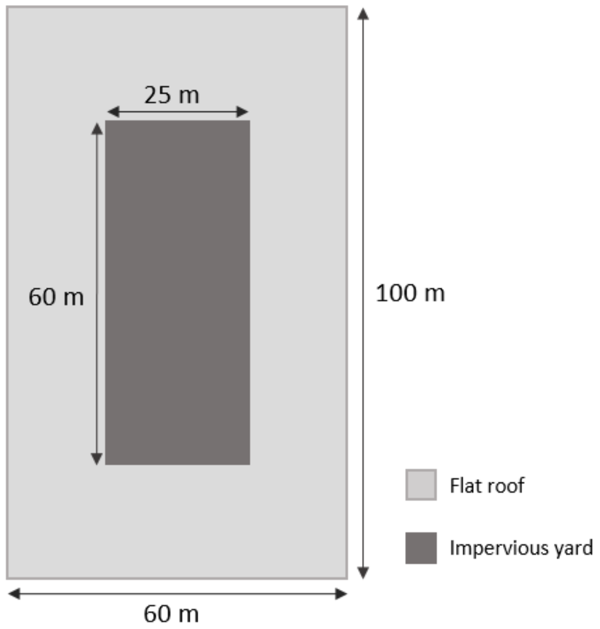

Figure 2: Step 1 configuration.

Parameters setting:

Parameter	Value
Roof surface area	4500 m^2
Yard surface area	1500 m^2

Results by the authors:

Precipitation (m^3)	Runoff (m^3)	Infiltration (m^3)	Retention (%)
11750	11750	0	0 %

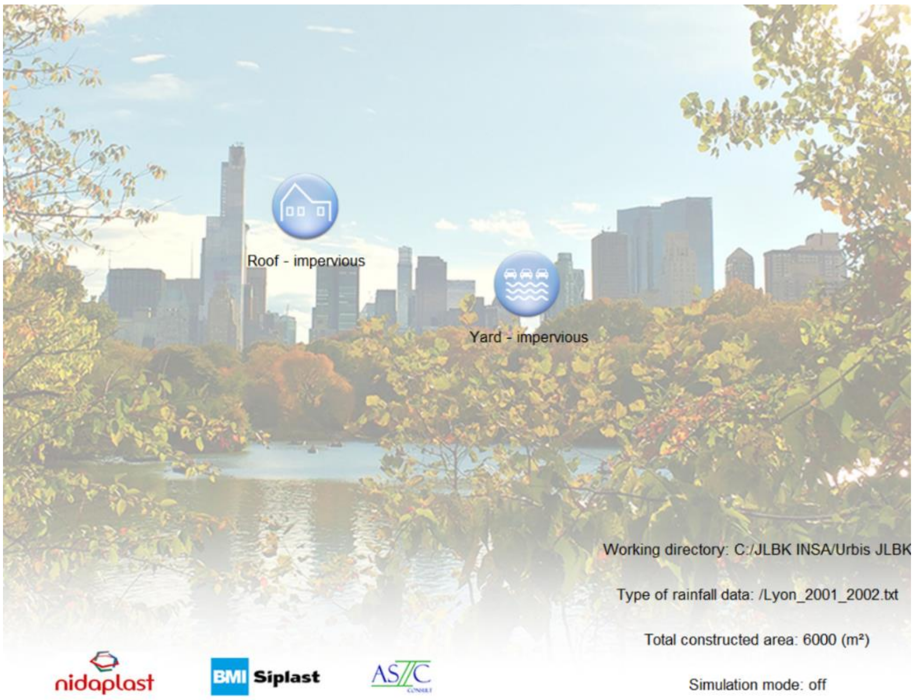

Figure 3: Step 1 setup.

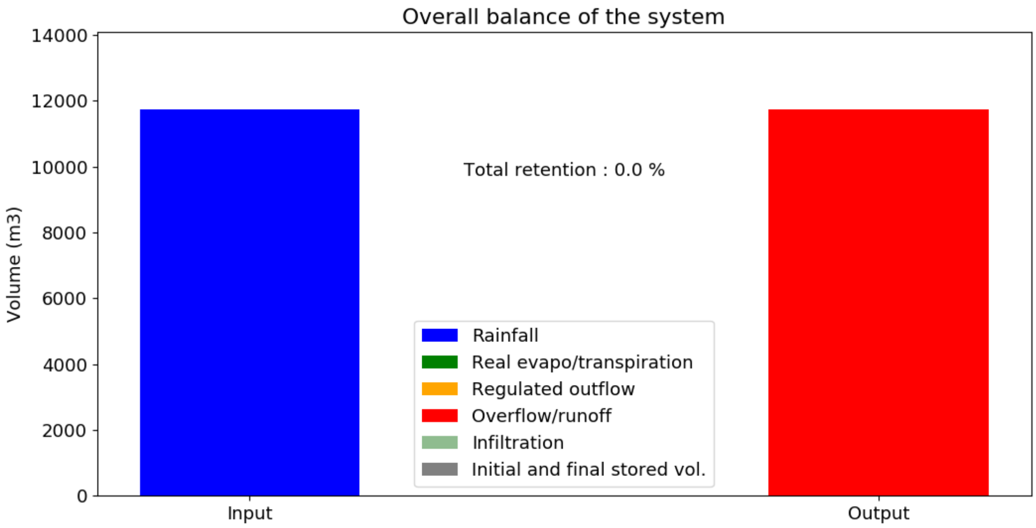

Figure 4: Step 1 global mass balance.

Step 2

The step 2 scenario is a flat roof and a yard composed of a garden and an impervious pavement of equal surfaces. The garden is simulated with natural grass. At this point, there is no link between all these techniques. Run the simulation.

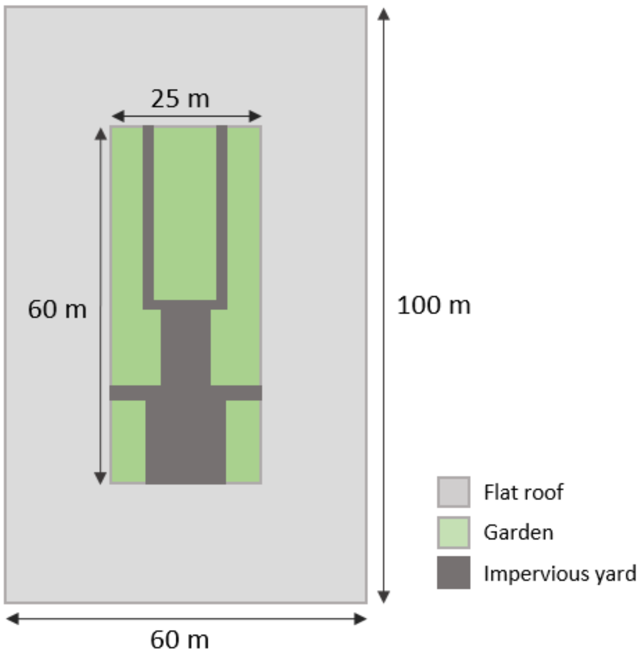

Figure 5: Step 2 scenario.

Parameters setting:

Parameter	Value
Roof surface area	4500 m^2
Yard surface area	750 m^2
Garden surface area	750 m^2
Pervious surface type	Natural grass
Permeability	0.05 m/s

Results by the authors:

Precipitation (m^3)	Runoff (m^3)	Infiltration (m^3)	Retention (%)
11750	10281	1469	12 %

Figure 6: Step 2 setup.

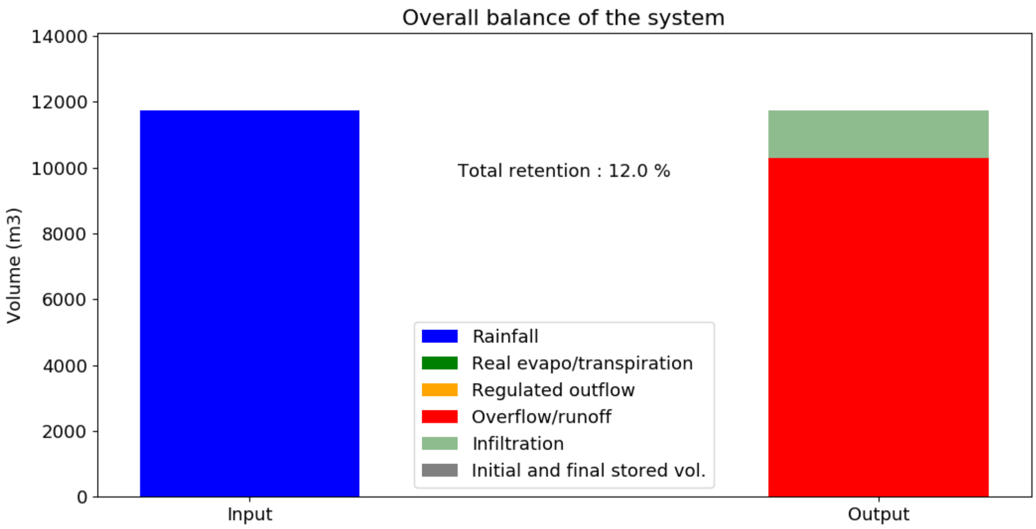

Figure 7: Step 2 global mass balance.

Step 3

In order to increase the permeability, the impervious yard is replaced by a permeable surface. Which type of surface seems to be the most adequate?

Parameters setting:

Parameter	Value
Roof surface area	4500 m^2
Yard surface area	750 m^2
Garden surface area	750 m^2
Garden surface type	Natural grass
Garden surface permeability	0.05 m/s
Yard surface type	Porous pavement
Yard surface permeability	0.005 m/s

Results by the authors:

Our option: permeable pavement to keep a walking surface clean and porous.

Precipitation (m^3)	Runoff (m^3)	Infiltration (m^3)	Retention (%)
11750	8812	2937	25 %

Figure 8: Step 3 setup.

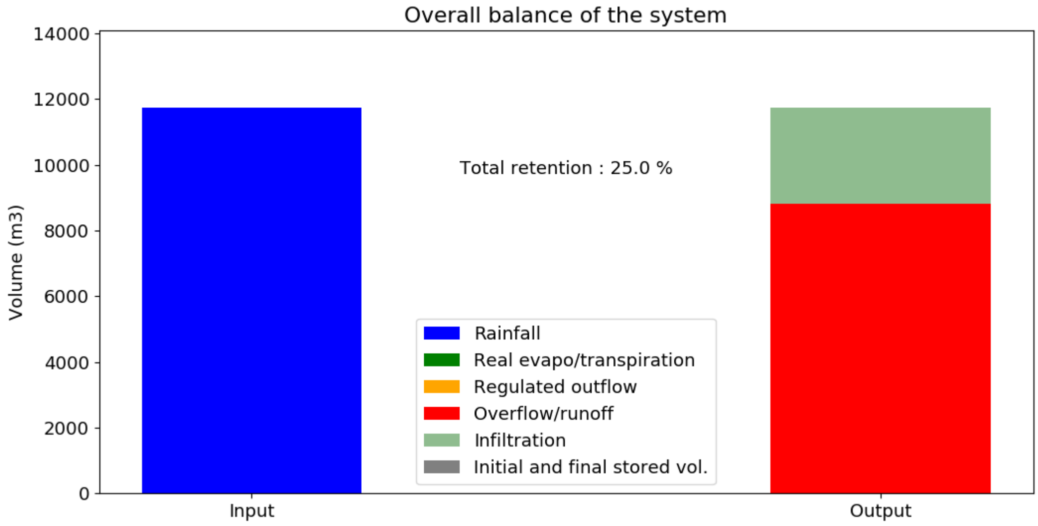

Figure 9: Step 3 global mass balance.

Step 4

The runoff is mainly due to the impervious flat roof. To reduce it, one option is to transfer the roof water to the porous pavement.

Hypothesis: the yard geometry may induce that the runoff is only transferred to the porous pavement. The connection is created with a pipe. The connection gutter generates an average lag time of 2 minutes.

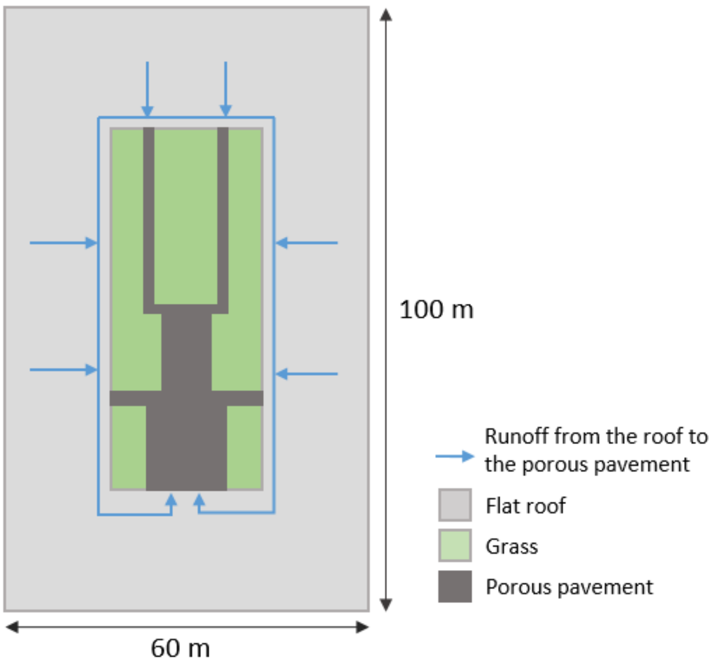

Figure 10: Step 4 scenario.

Parameters setting:

Parameter	Value	Parameter	Value
Roof surface area	4500 m^2	Lag time	2 minutes
Yard surface area	750 m^2		
Garden surface area	750 m^2		
Garden surface type	Natural grass		
Garden surface permeability	0.05 m/s		
Yard surface type	Porous pavement		
Yard surface permeability	0.005 m/s		

Results by the authors:

Precipitation (m^3)	Runoff (m^3)	Infiltration (m^3)	Retention (%)
11750	667	11083	94 %

Figure 11: Step 4 setup.

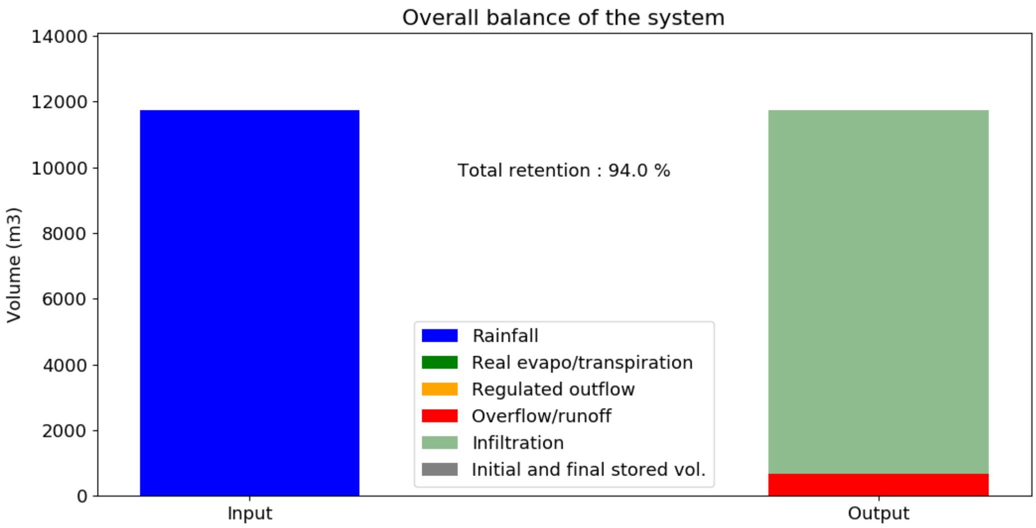

Figure 12: Step 4 global mass balance.

Step 5

The previous solution significantly increased the global permeability of the area. However, it seems not acceptable for the owner. He fears the heavy rains and does not want the yard to become a swimming pool as infiltration may be not fast enough for some intense events. He would like to know the results if he builds a green roof.

Hypothesis: the new scenario is composed of 1-meter large walkway all around the green roof. This path is slightly inclined to direct the runoff toward the green roof. The alveolus structure height is H_{alv} = 170 mm. A regulated flow is set to Q = 1 L/s and is activated from the water level h_{alv} = 150 mm (overflow level must be higher than the regulated flow level).

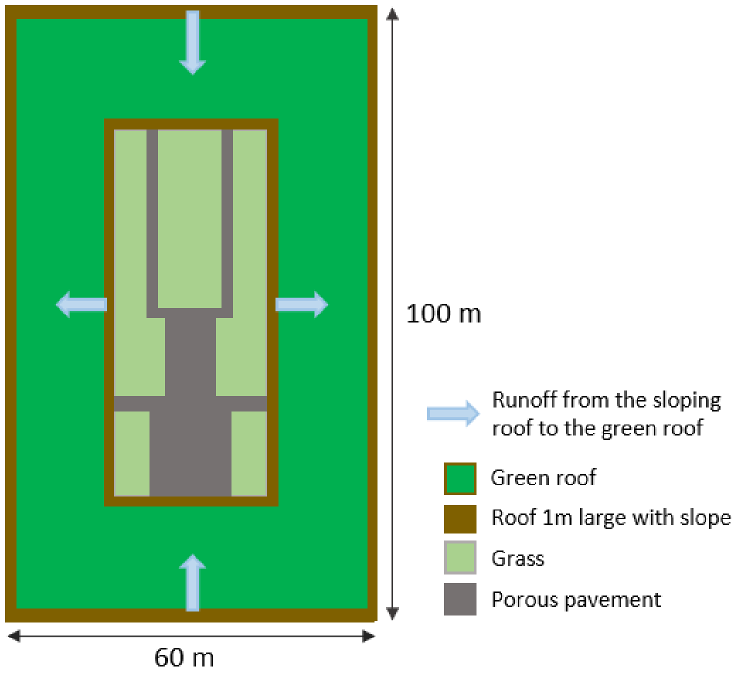

Figure 13: Step 5 scenario.

Parameters setting:

Parameter	Value	Parameter	Value
Green roof surface area	4018 m^2	Garden surface area	750 m^2
Surface area of the roof walkway	482 m^2	Garden surface type	Natural grass
Substrate thickness	60 mm	Garden surface permeability	0.05 m/s
Void index of the alveolus structure	0.95	Yard surface area	750 m^2
Alveolus structure height	170 mm	Yard surface type	Porous pavement
Overflow discharge height	170 mm	Yard surface permeability	0.005 m/s
Height of outflow controller	0 mm	Lag time (transfer from walkway to green roof)	2 minutes
Max accepted regulated outflow	1 L/s		

Results by the authors:

Precipitation (m^3)	Evapo-transpiration (m^3)	Regulated outflow (m^3)	Runoff (m^3)	Infiltration (m^3)	Retention (%)
11750	51	8639	0	2937	26 %

Figure 14: Step 5 setup.

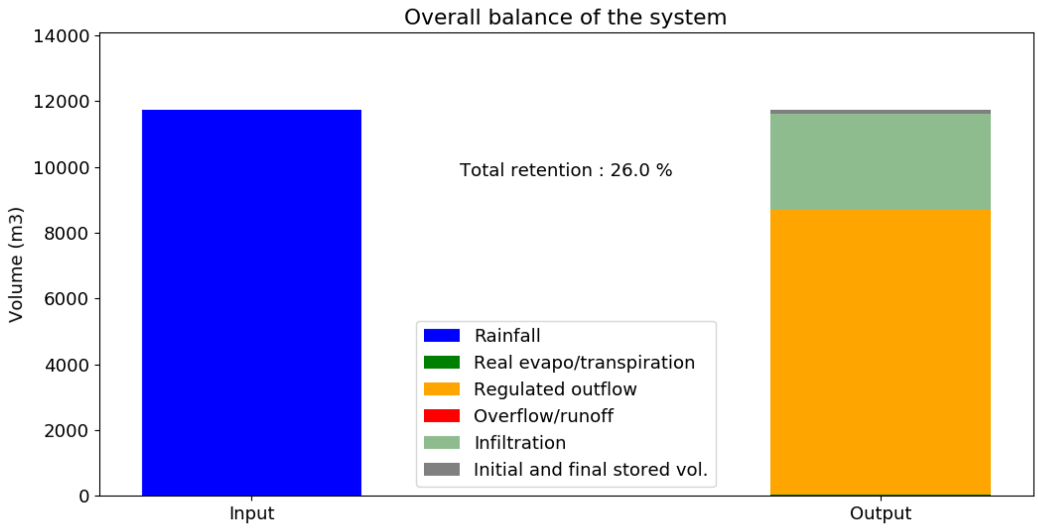

Figure 15: Step 5 global mass balance.

Step 6

The design office proposes the owner an alternative scenario with a basin to store half of the runoff from of the roof. The other half will be transferred to the porous pavement as described in step 4.

Hypothesis: half of the roof runoff is transferred to a 150 m^3 underground basin by means of a pipe. The tank dimensions are width 5 m * length 10 m * depth 3 m. It is suggested to try two sub-scenarios where the tank is pervious (permeability 0.002 m/s) or impervious (in this last case, the water remains stored in the tank). The other half of the roof runoff is transferred to the yard with porous pavement. The connection is created with a pipe. Both pipes generate a transfer lag-time of 2 minutes.

In this case, there is no regulated outflow from the underground storage basin. What would be the results if a regulated outflow is added?

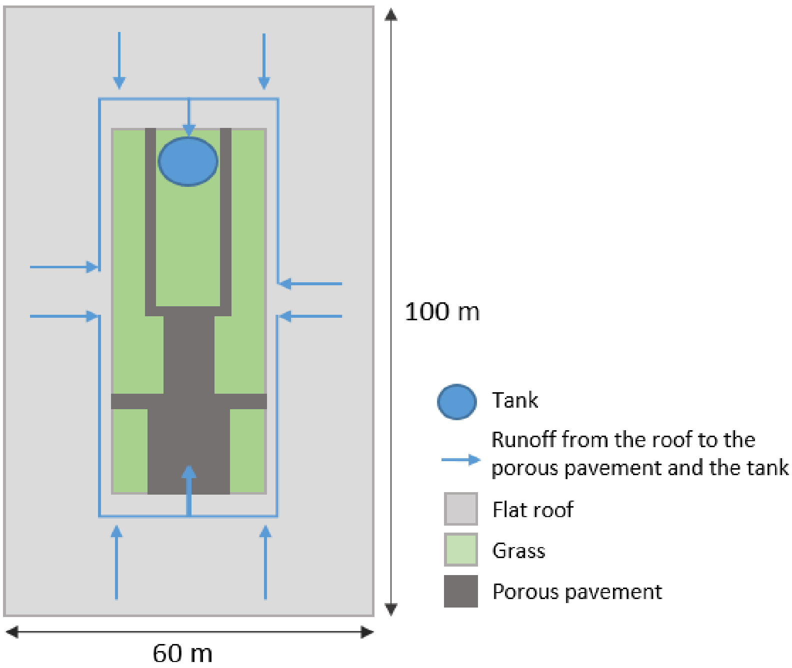

Figure 16: Step 6 scenario.

Parameters setting:

Parameter	Value	Parameter	Value
Roof 1 surface area	2250 m^2	Garden surface area	750 m^2
Roof 2 surface area	2250 m^2	Garden surface type	Natural grass
		Garden surface permeability	0.05 m/s
Basin type	Underground basin	Yard surface area	750 m^2
Type of underground basin	Tank	Yard surface type	Porous pavement
Basin surface area	50 m^2	Yard surface permeability	0.005 m/s
Total basin depth	3000 mm		
Overflow discharge height	3000 mm	Lag time (for both pipes)	2 minutes
Regulated flow discharge height	0 mm		
Max accepted regulated outflow	0 L/s		
Basin permeability	0.002		

Results by the authors:

Type of basin	Precipitation (m^3)	Evapo-transpiration (m^3)	Regulated outflow (m^3)	Runoff (m^3)	Infiltration (m^3)	Final retention (m^3)	Retention (%)
Impervious	11750	0	0	4407	7193	150	62 %
Pervious	11750	0	0	151	11599-	0	99 %

Figure 17: Step 6 setup.

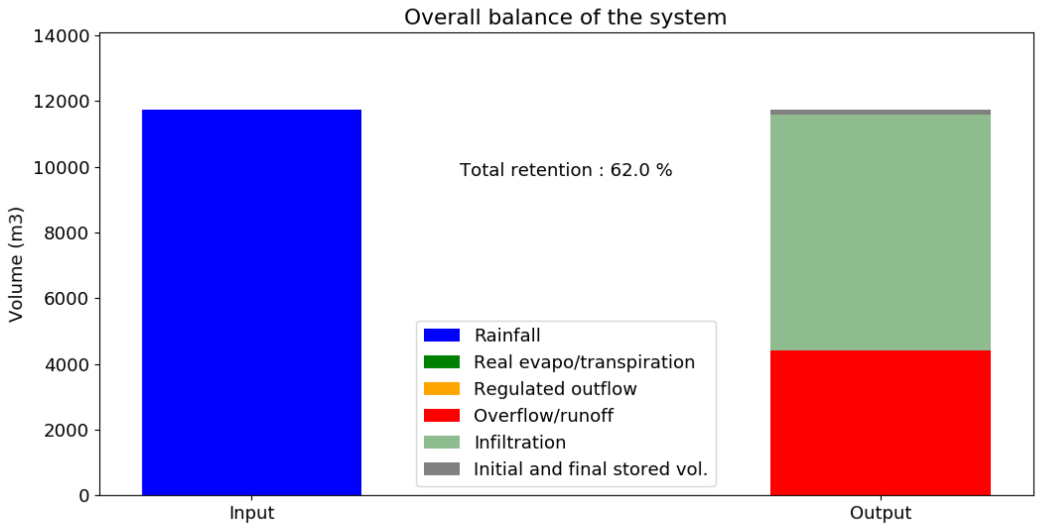

Figure 18: Step 6 global mass balance with an *impervious* underground tank. The tank is full from 28/02/2001 and remains full as there is no outflow: this water could be used e.g. for watering the garden, toilet flushing, or other possible uses of harvested rainwater.

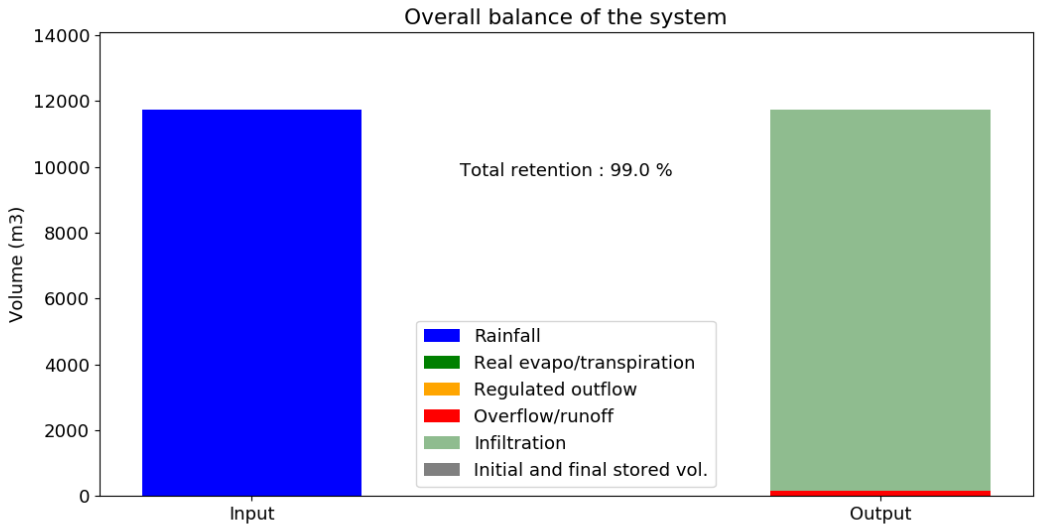

Figure 19: Step 6 global mass balance with a *pervious* underground tank.

Step 7

The tank proposed in step 6 convinces the owner who, however, still does not want the pipe to transfer water from the roof to the porous pavement and would like to investigate the combination of the tank and the green roof to check if a global retention of 50 % could be achieved.

Hypothesis: the step 7 scenario is composed of 1-meter large walkway all around the green roof. This path is slightly inclined to transfer the runoff to the green roof substrate. The alveolus structure height is H_{alv} = 170 mm. A regulated flow is set to Q = 1 L/s and is activated from the water level h_{alv} = 150 mm.

The roof runoff is transferred to a 150 m^3 tank by means of a pipe which generates an average transfer lag-time of 2 minutes.

In this case, there is no regulated outflow from the underground storage basin. What would be the results if a regulated outflow is added?

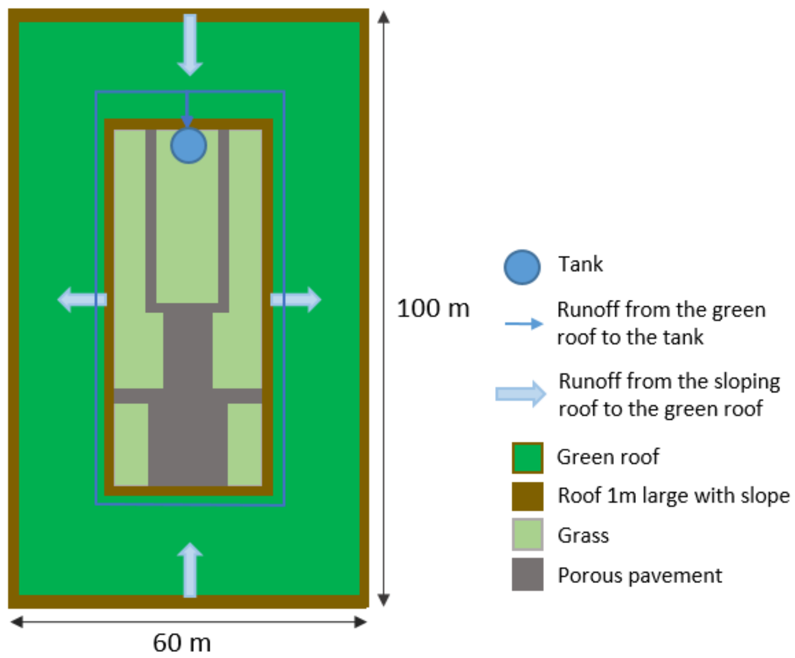

Figure 20: Step 7 scenario.

Parameters setting:

Parameter	Value	Parameter	Value
Green roof surface area	4018 m^2	Garden surface area	750 m^2
Surface area of the roof walkway	482 m^2	Garden surface type	Natural grass
Substrate thickness	60 mm	Garden surface permeability	0.05 m/s
Void index of the alveolus structure	0.95	Yard surface area	750 m^2
Alveolus structure height	170 mm	Yard surface type	Porous pavement
Overflow discharge height	170 mm	Yard surface permeability	0.005 m/s
Regulated flow discharge height	150 mm		
Max accepted regulated outflow	1 L/s	Lag time (for all pipes)	2 minutes
Basin type	Underground basin		
Type of underground basin	Tank		
Basin surface area	50 m^2		
Total basin depth	3000 mm		
Overflow discharge height	3000 mm		
Regulated flow discharge height	0 mm		
Max accepted regulated outflow	0 L/s		
Basin permeability	0.002		

Results by the authors:

Type of Basin	Precipitation (m^3)	Evapo-transpiration (m^3)	Regulated outflow (m^3)	Runoff (m^3)	Infiltration (m^3)	Final retention (m^3)	Retention (%)
Impervious	11750	520	0	7468	2937	823	36 %
Pervious	11750	520	0	0	10555	673	100 %

Introducing a regulated outflow from the basin does not help to increase total retention, but it is effective to avoid overflow. Similarly, a regulated outflow in a vegetated roof is counterproductive as it reduces evapotranspiration.

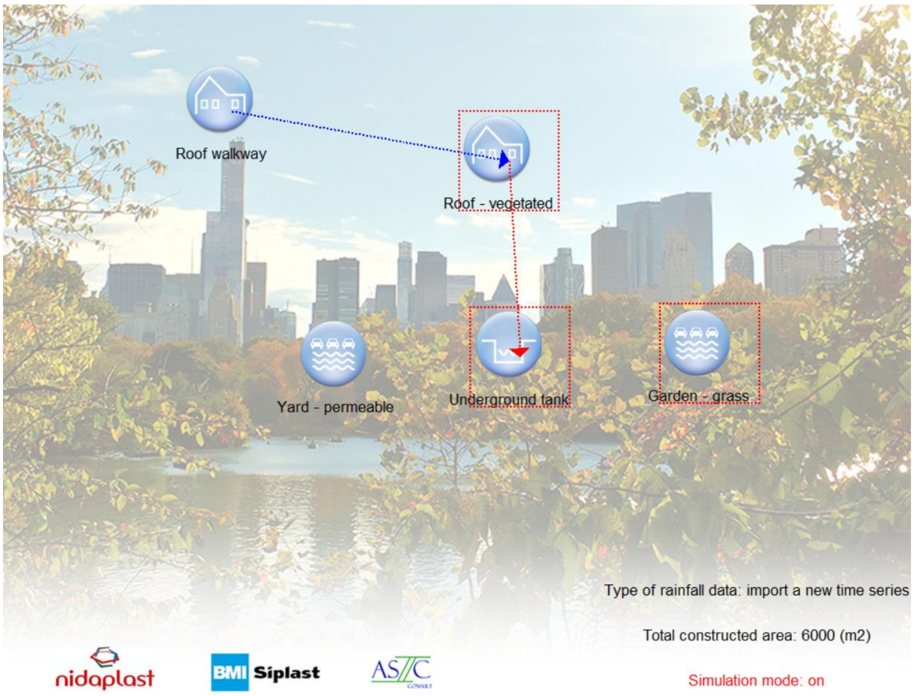

Figure 21: Step 7 setup.

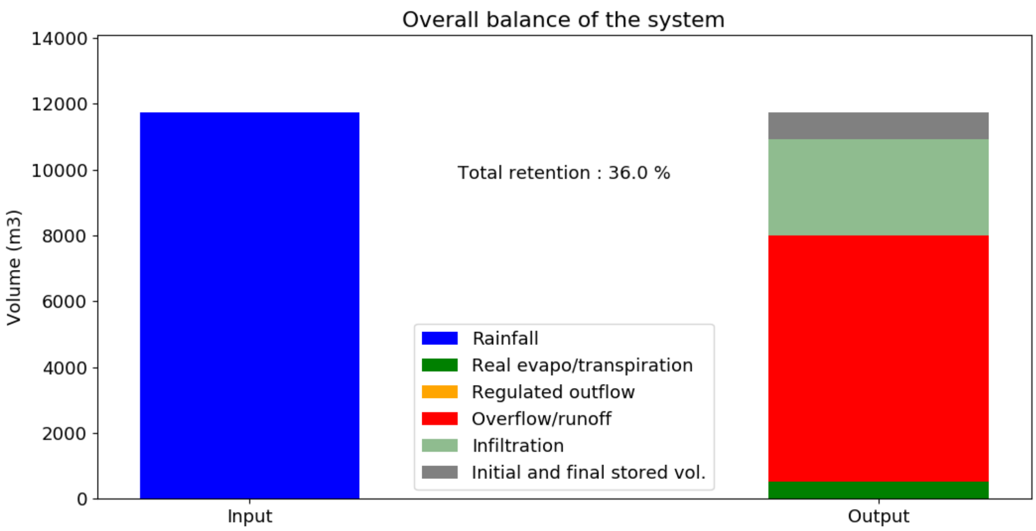

Figure 22: Step 7 global mass balance with an *impervious* underground tank.

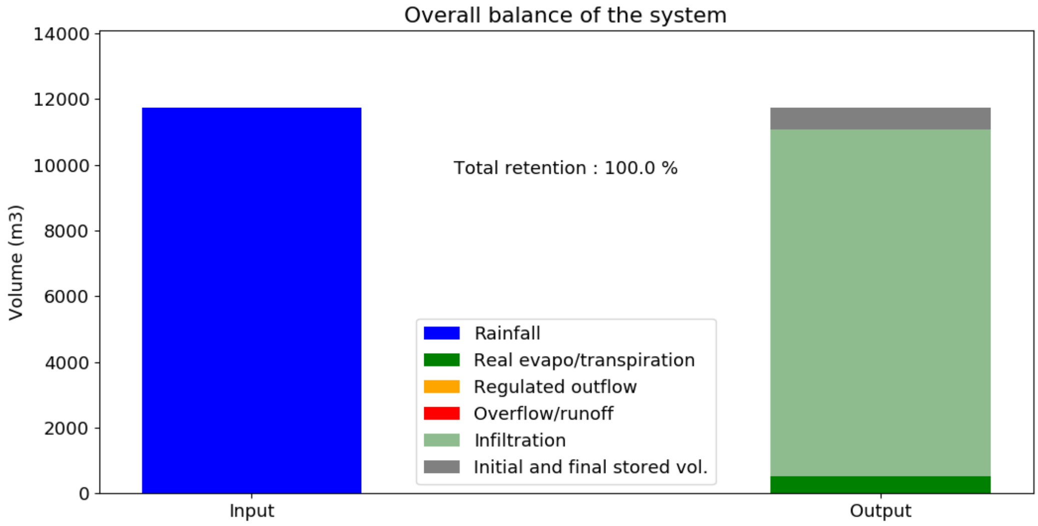

Figure 23: Step 7 global mass balance with a *pervious* underground tank.