Sustainable drainage systems as ecosystem services
Case study: urban catchment in the city of Montevideo, Uruguay

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Introduction

This research explores if Green infrastructure at large scales within an urban catchment can serve as a sustainable solution to better manage storm water run-offs, and at the same time provide other services to the society.

***Problem definition*:**
Urban floods due to increase of impermeable surface

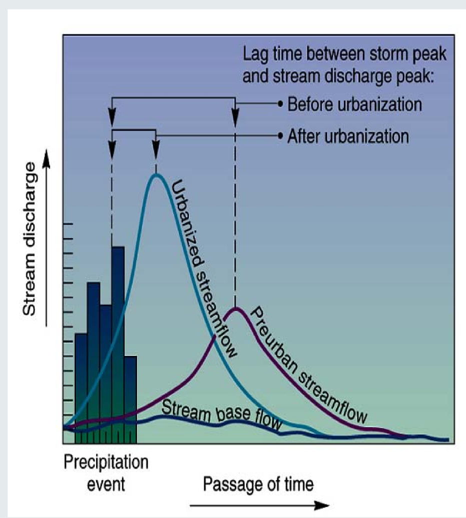


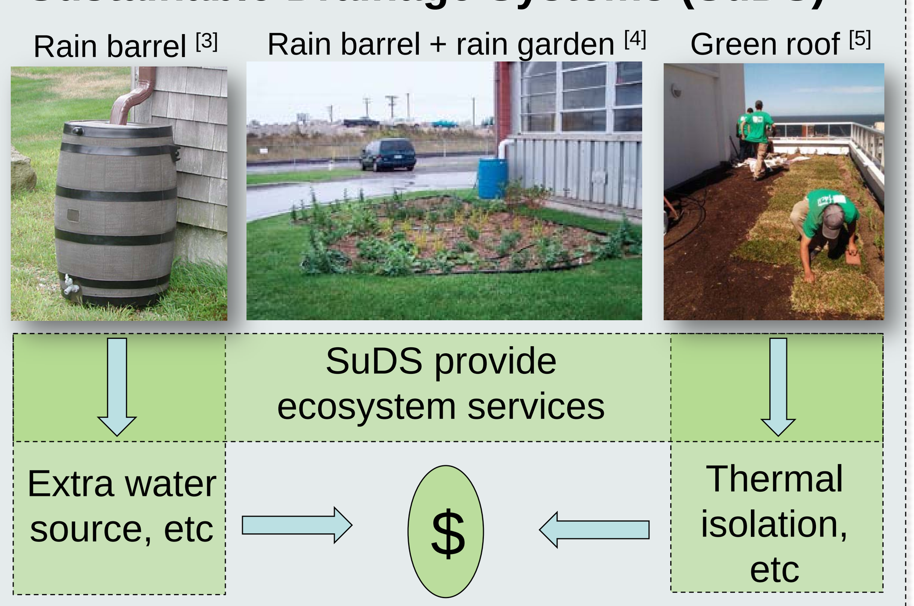
Figure 1 Impact of urbanization on stream flows [1]

Traditional solutions:
Pipes, pumps: Efficient Conveyance

Figure 2 Storm water sewer [2]

Alternative solutions: lessen the flow

Sustainable Drainage Systems (SuDS)



***Research objectives*:**
- Quantify and value ecosystem services of rain barrels and green roofs
- Optimize their layout by including these benefits in economic analysis.

Ecosystem services considered:
- Rain barrels: main water saving, energy & carbon emissions saving (less water treated);
- Green roofs: energy & carbon emissions saving (building isolation & less water treated), property value uplift, food production, increase of roof longevity, air pollution removal, aesthetics.

Case study area: Upper Quitacalzones
- Catchment of 235 ha of urban area;
- Combined sewer system with conveyance capacity deficit;
- 610 houses regularly flooded by storms of Tr > 3 years;
- Approximately 18 million US$ of flooding cost;
- Roof area ~ 64% of total catchment area.

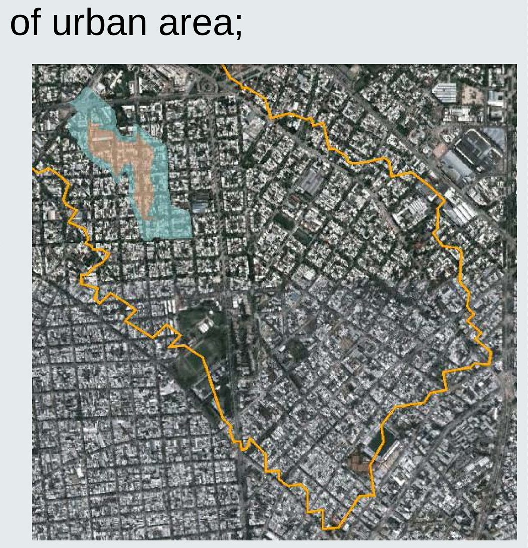
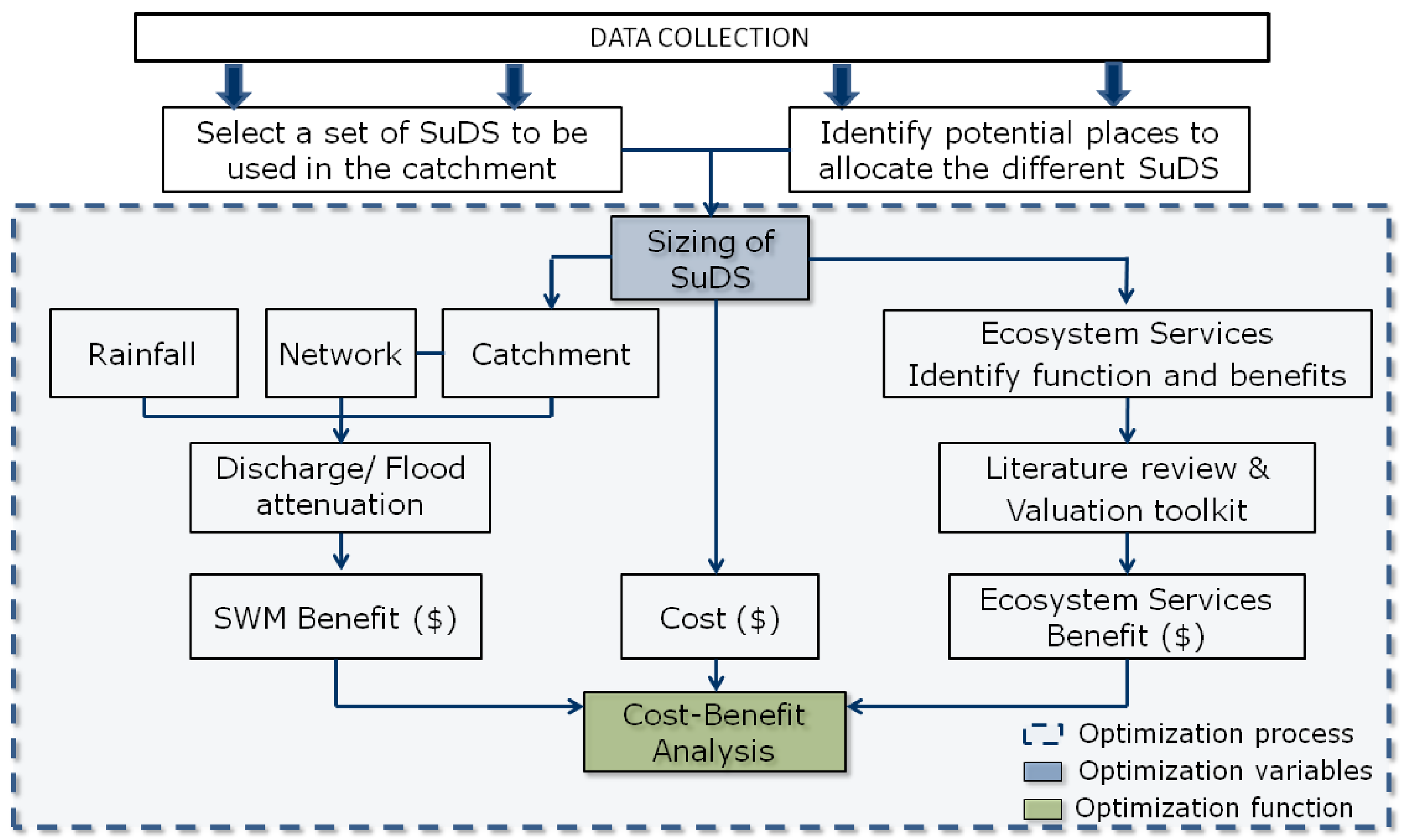


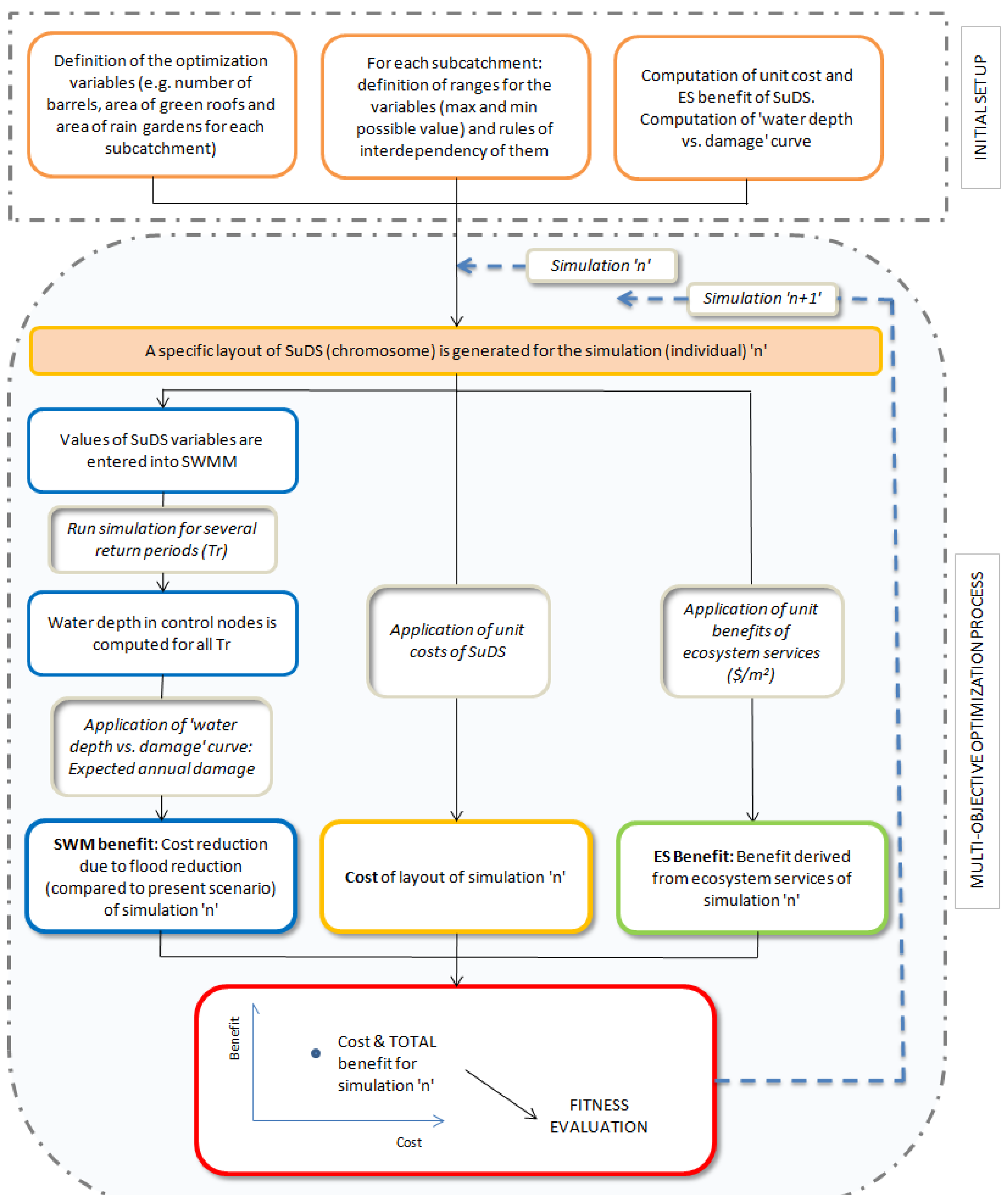
Figure 3 Flooded areas for rainfalls of 5 and 20 years of return period

Materials and methods

General methodology:



Optimization methodology :



This process is performed for 4 different scenarios (see results)

Results

Costs and benefits of SuDS & Optimization

- Solutions with **Green Roofs (GR)** and **Rain Barrels (RB)** as SuDS;
- Total costs computed for each SuDS; looked at solutions with cost < 35 million US$
- Total benefits composed by **ecosystem services (ES)** benefits and **storm water management (SWM)** benefits;
- Present values are computed for a 30 years lifespan.

Table 1 Present values of costs and ES benefits of SuDS

	PV Cost	PV Benefit	NPV
Rain barrel (US$/barrel)	300	125	-175
Green roof (US$/m²)	142	132	-10

- Probabilistic analysis of NPVs (SWM benefits not included):

Table 2 Maximum, minimum and most probable values

	NPV - 80% confidence interval	Most probable NPV
Rain barrel (US$/barrel)	[-260, -60]	-180
Green roof (US$/m²)	[-100, 50]	-10

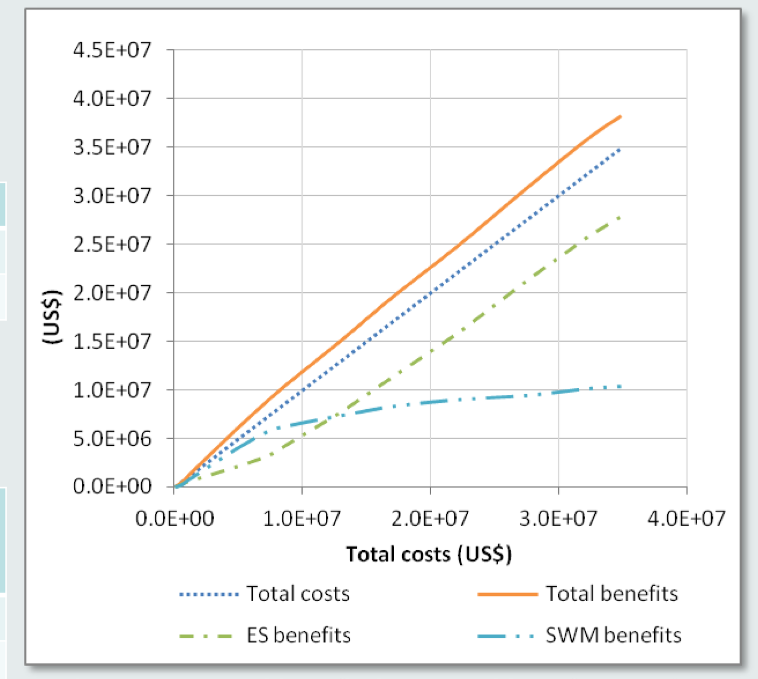


Figure 4 Cost and benefit decomposition of Pareto front

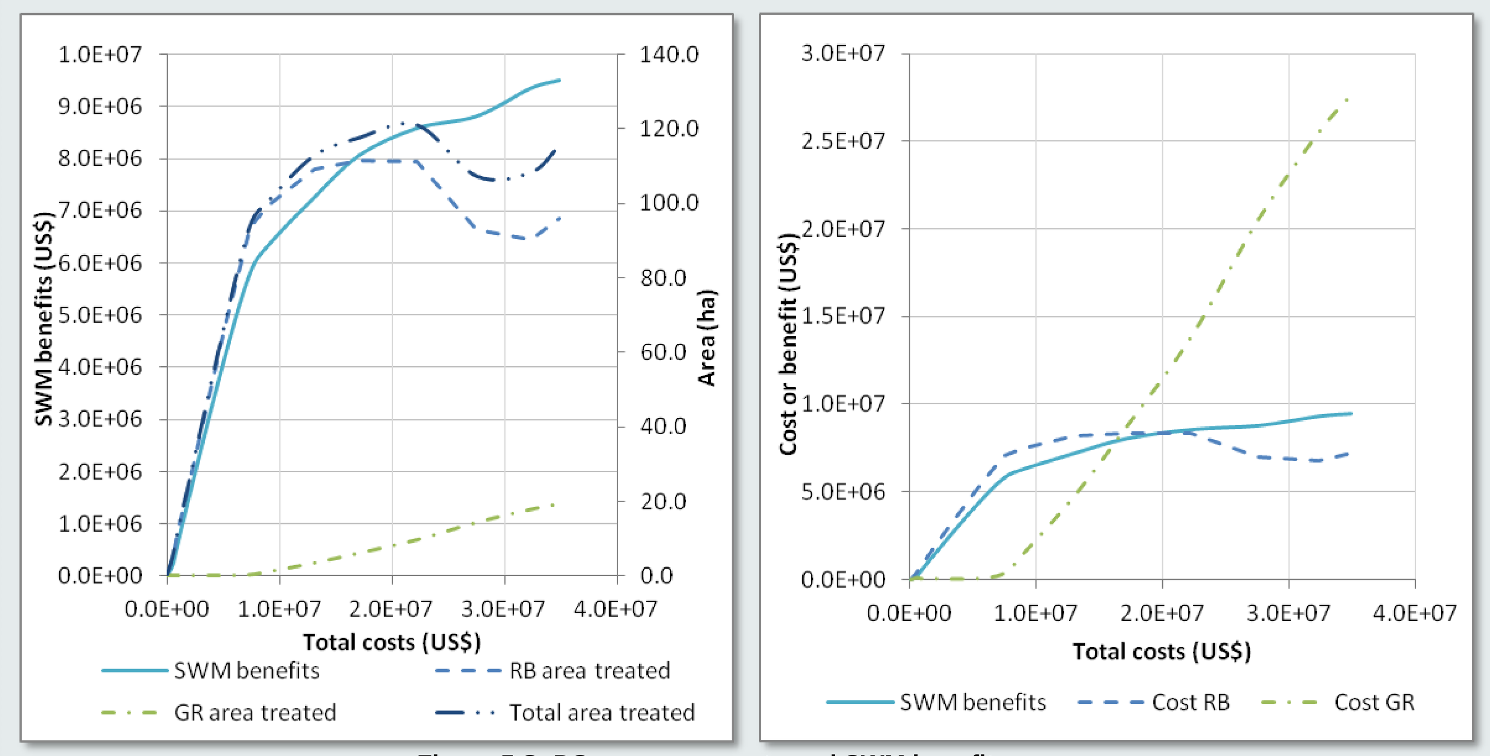


Figure 5 SuDS coverage, costs and SWM benefits

Also analyzed when the sizing of **3 underground storages** is included in the optimization process (storages only provide SWM benefits in this case study), added to the green roofs and rain barrels.

Figures 6 and 7 show the results of the four scenarios assessed (Table 3):
- two **including ES** benefits (one with storages and one without storages);
- two **not including ES** benefits (one with storages and one without storages)

Table 3 Four scenarios assessed

	With ES	Without ES
SuDS	Scenario 1	Scenario 2
SuDS & storages	Scenario 3	Scenario 4

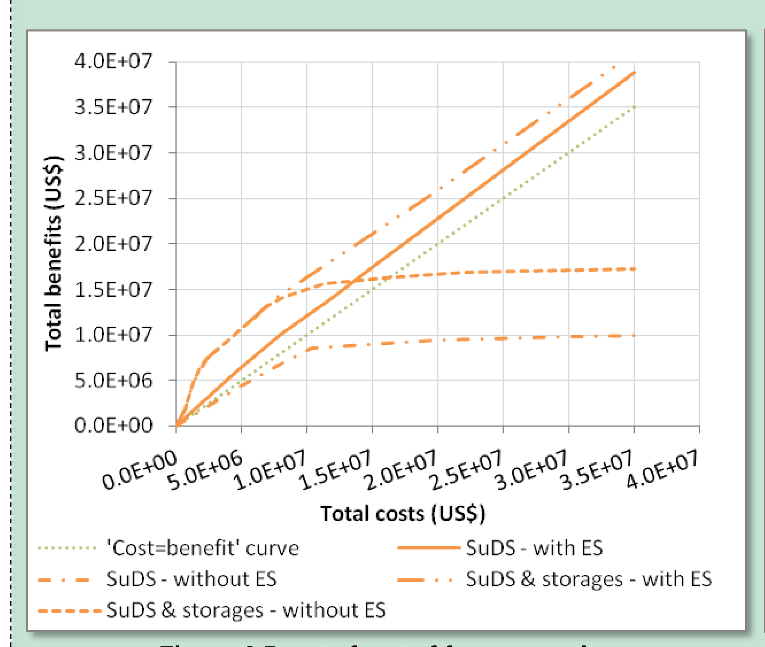


Figure 6 Pareto front of four scenarios

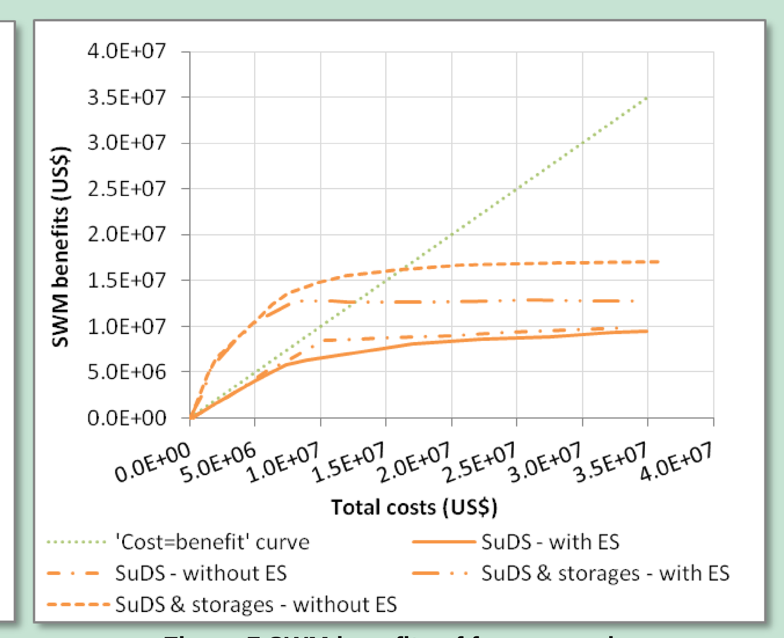


Figure 7 SWM benefits of four scenarios

Conclusions

1. **The inclusion of ecosystem services (ES) benefits justifies investments on sustainable drainage systems (SuDS) that would not otherwise be profitable.**
2. **When SuDS and storages are considered, the largest flood reductions are achieved.**
3. **Solutions with storages are more cost effective than solutions with only SuDS.**
4. **Green roofs & rain barrels have similar runoff reduction per area treated. However, rain barrels are cheaper and, therefore, more cost-effective.**
5. **Green roofs are cost effective only when part of the flooding costs have been already eliminated. Otherwise, storages or rain barrels are preferred.**
6. **If ES benefits were not considered, installation of green roofs would not be justified at all. Rain barrels would also not be profitable in that case, but are much closer to be so.**

References

[1] Christopherson, RW (2003) Geosystems: An Introduction to Physical Geography (5th Edition). Prentice Hall, Upper Saddle River, NJ

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