A new tool for quantifying the hydrological effects of LID retrofit designs – the power of simplicity

Lerer, Sara Maria; Sørup, Hjalte Jomo Danielsen; Arnbjerg-Nielsen, Karsten; Mikkelsen, Peter Steen

Publication date:
2016

Document Version
Peer reviewed version

A new tool for quantifying the hydrological effects of LID retrofit designs – the power of simplicity

Sara Maria Lerer[1], Hjalte Jomo Danielsen Sørup[2], Karsten Arnbjerg-Nielsen[3] and Peter Steen Mikkelsen[4]

[1]DTU Environment, Technical University of Denmark, Bygningstorvet Building 115, 2800 Kgs. Lyngby, Denmark; Ph (+45) 45251432; email: smrl@env.dtu.dk
[2]DTU Environment, Technical University of Denmark, Bygningstorvet Building 115, 2800 Kgs. Lyngby, Denmark; Ph (+45) 45251590; email: hjds@env.dtu.dk
[3]DTU Environment, Technical University of Denmark, Bygningstorvet Building 115, 2800 Kgs. Lyngby, Denmark; Ph (+45) 45251450; email: karn@env.dtu.dk
[4]DTU Environment, Technical University of Denmark, Bygningstorvet Building 115, 2800 Kgs. Lyngby, Denmark; Ph (+45) 45251605; email: psmi@env.dtu.dk

ABSTRACT: We developed a new tool to address the needs of utility companies in the early planning and design phase of LID for retrofitting in existing urban areas, where a high degree of collaboration among stakeholders with different professional backgrounds is needed. The tool uses simplified methods to assist the user in quickly assessing two key overall performance indicators of a LID plan: 1. Return period for overflow, and 2. Impact on the annual water budget of the catchment. The tool currently allows combining three types of stormwater control measures (SCMs) commonly used in LID: permeable paving, bioretention units and local detention ponds. We present a case study to illustrate the usefulness of the tool in the context of climate change adaptation in Copenhagen and discuss further development plans including more SCMs, better user interface and assessing the uncertainties introduced by the simplifications in the tool.
KEY WORDS: Low impact development, water sensitive urban design, sustainable urban drainage systems, planning, communication;

OBJECTIVE

Planning for Low Impact Development (LID), also called Water Sensitive Urban Design (WSUD) and Sustainable Urban Drainage Systems (SUDS) (Fletcher et al. 2015), requires a significantly higher degree of collaboration between drainage engineers and other stakeholders compared with traditional underground pipe-based drainage systems. Tools developed to inform decisions regarding LID are often either very data intensive and complex or very simple and general (Lerer, Arnbjerg-Nielsen, and Mikkelsen 2015). We developed a new tool to specifically address the needs of Danish utility companies in the early planning and design phase of LID for retrofitting in existing urban areas, where local constraints and opportunities must be taken into account.

METHOD

A critical point of departure for the development of the tool was a need to reduce the complexity of drainage systems performance to a small number of key indicators that can be understood across professional backgrounds. We identified two main hydrological criteria:

1. The ability to protect against flooding;
2. The ability to maintain/mimic a natural hydrology of the catchment.

Other priorities in the conceptual development included high user friendliness and fast results that are easy to communicate to non-water professionals. For this reason we chose a map-based approach, where the user can draw areas from which runoff needs to be managed and sub-areas herein they wish to designate to different LID structures. Hydraulic conductivity of the native soil is the only additional input required. Information about LID type, area ratio (between LID area and connected runoff area) and soil conductivity is then transformed into performance criteria using look-up tables derived from model simulations using SWMM LID, in a manner similar to what was done by Henrichs et al. (2016). In this way the tool is made free from time series and thus significantly simpler to use than usual dynamic simulation tools.

We chose to represent the first criterion using the Three Point Approach (3PA), which has been shown to improve communication among stakeholders regarding the ability of different drainage solutions to meet expectations (Fratini et al. 2012). The 3PA defines three domains of urban water management: A) the everyday domain, where values such as sustainability and amenity dominate the view of rainwater, B) the design domain, where rules and regulations regarding proper management of stormwater dominate, and c) the extreme domain, where plans are made as to how to increase resilience towards rare flooding events. We adapted the original approach to a quantitative context by choosing a specific return period to define each domain, and associated a typical rainfall depth to each domain, based on statistical analysis of long term rainfall records (Sørup et al., n.d.) , see **错误!未找到引用源。** .

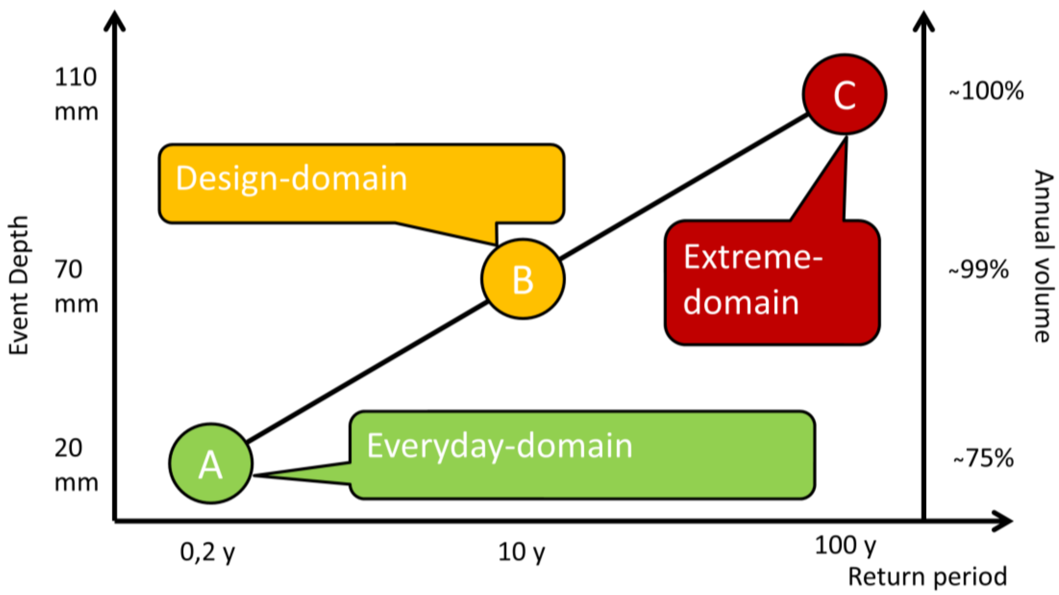

Figure 1: The Three Point Approach, adapted from (Fratini et al. 2012) **and** (Sørup et al., n.d.)**.**

We chose to represent the second criterion using a water budget approach, focusing exclusively on the fate of water from impermeable surfaces in order to sharpen the contrast between urban hydrology in the present situation and a future with LID retrofit implementation. We do not target pollution issues directly in this tool, but we point out that the larger the fraction of the annual water budget that is controlled in local WSUD-elements, the higher the probability that a significant proportion of the pollution is also retained and treated locally.

CASE STUDY

We illustrate the tool functionality by demonstrating its application to a case study in Copenhagen, Denmark. Copenhagen is a frontrunner city in terms of making plans for adaptation to future precipitation regimes expected as a consequence of global warming (Index 2013; Gerdes 2012; City of Copenhagen 2011). Part of the climate adaptation plan includes the retrofit of existing roads into "green roads", which are intended to "remove and retain the water locally, typically on smaller roads, for example private shared roads" (City of Copenhagen 2015).

This type of initiative is supported by new national legislation that allows for co-funding of climate adaptation measures between utility companies and private land owners (Konkurrence og Forbrugerstyrelsen 2015). However, the interests of these stakeholders in such projects are expected to differ: the utility company is generally interested in a large reduction of the hydraulic load on the city drainage network for the lowest price possible, while the land owners are generally interested in local asset management, i.e. reducing the local flooding risk while increasing the local amenity value. Given that there are no clear design criteria for a green road (yet), there is room for negotiation in each case, which can be supported by our tool.

Ny Ryvang Villakvarters Vejlaug is an association of home owners concerned with the maintenance of the shared roads in their residential area, located in the northern part of Copenhagen. The entire area of the association covers about 6,4 ha, of which about 0,7 ha (~10%) are roads and pavements. The soil type in the area is predominantly boulder clay with expected values of hydraulic conductivity ranging from 1E-10 – 1E-6 m/s. The SCM preferred by the residents is bioretention units formed as bump-outs, since they are expected to contribute with added value in terms of aesthetics richness and traffic regulation.

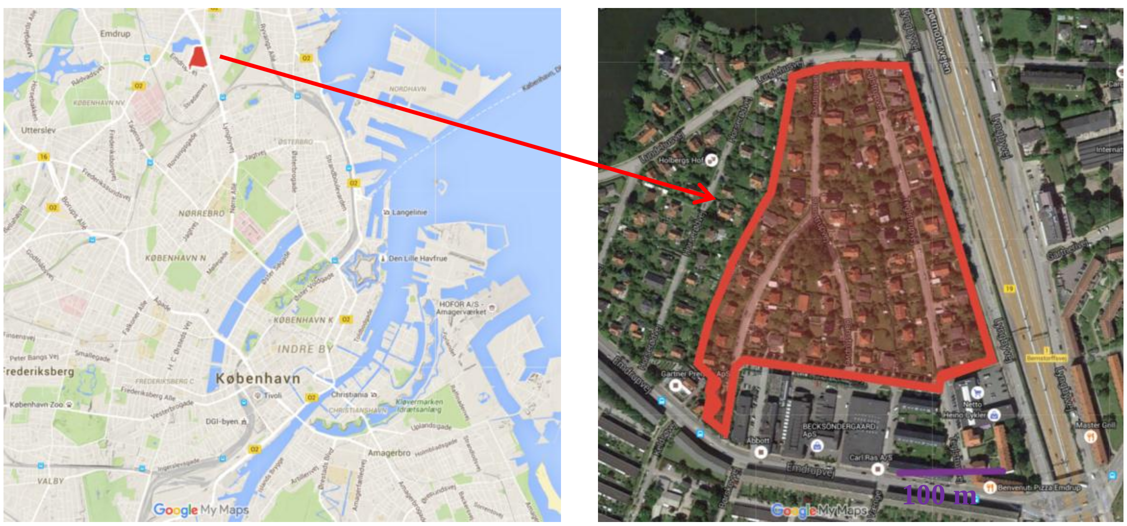

Figure 2: Illustration of the location and character of the Ny Ryvang case study area.

RESULTS

The tool is used to quickly asses the expected impact of several variations of the suggested LID retrofit plan for a sub-catchment of the Ny Ryvang home owners association. An assessment of the road area that can be repurposed to bump-outs yielded an area ratio of up to 10% LID. Assuming the bioretention units have no underground storage and the native soil has a hydraulic conductivity of 1E-6 m/s, the performance predicted is illustrated in Figure 3, part A: The return period for overflow from the bioretention units is around 0.3 years, i.e. there will be runoff from the catchment on average 3 times per year; on an annual basis around 80% of the water will infiltrate to the local groundwater. This is considered a rather satisfying performance, although it does not alleviate the need for a conveyance system to remove the excess runoff.

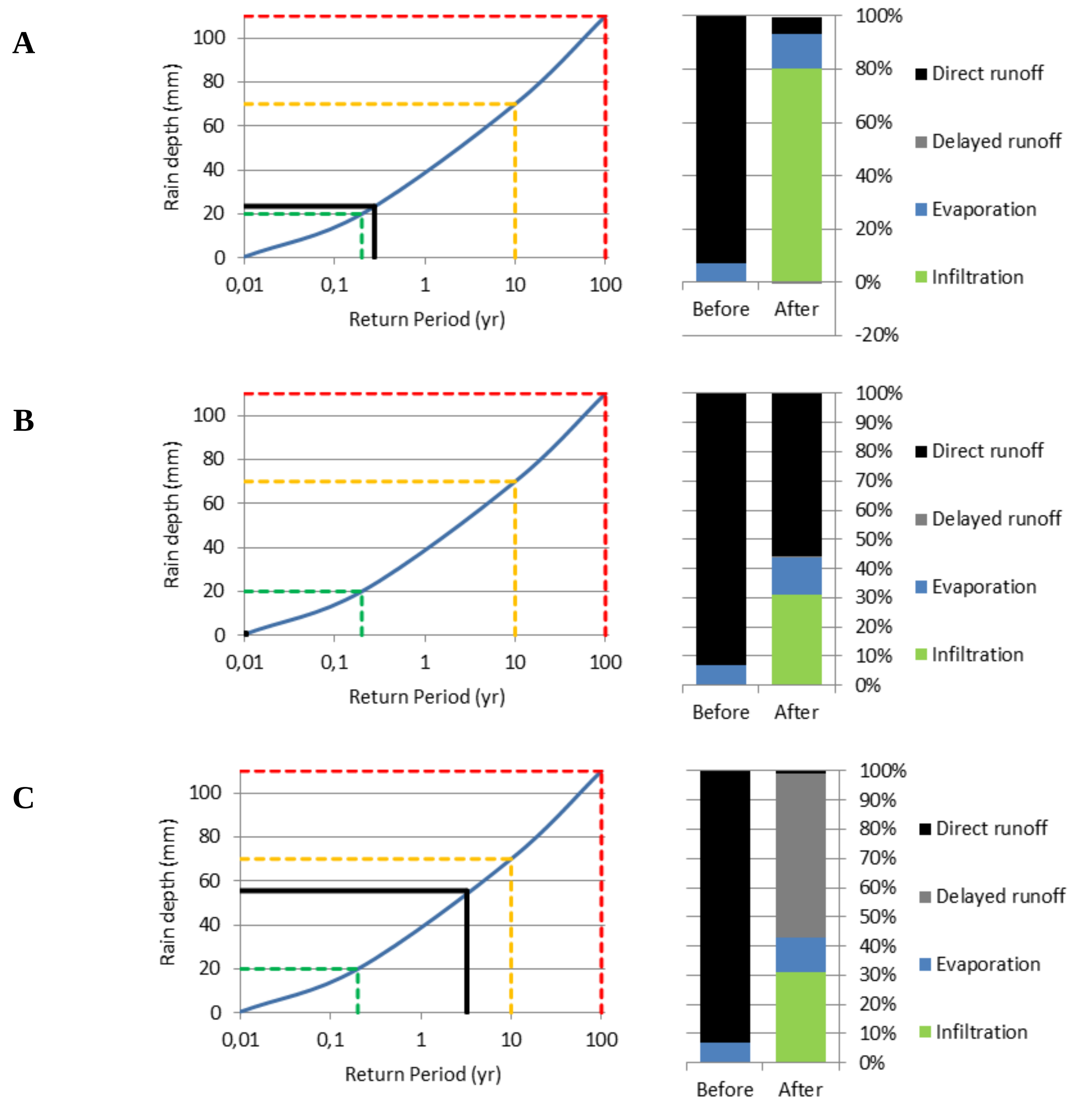

Figure 3: Key indicators predicted by the tool for three different scenarios.

However, if the conductivity of the soil is only around 1E-7 m/s, the performance would be significantly lower, as shown in Figure 3, part B: the return period for overflow is around 0.01 years, i.e. runoff will occur practically every time it rains, and on a yearly basis only 30% of the runoff will infiltrate locally.

This could be improved if the bioretention cells are upgraded with a subsurface storage volume. In this case, as shown in Figure 3, part C, the return period for overflow is around 3 years; still, only around 30% of the runoff is infiltrated, but an additional 50% is treated by percolation through the bioretention unit and is detained in the subsurface storage before it is slowly released to the drainage network.

DISCUSSION

The tool concept presented here is intended for use in the initial phases of a new LID retrofit project. An underlying assumption for the tool design is that at this stage there is a large uncertainty regarding the aims of the project as well as regarding the available means for achieving the aims, in terms of e.g. engagement, funding, preferred SCMs, space availability and physical characteristics of the area. Given all these uncertainties it seems cumbersome to set up detailed models, yet there is a need to have a qualified assessment of the magnitudes of impacts that can be expected from the different LID designs envisaged. Hence we argue that the uncertainty introduced by the simplifications made in the calculation approach in the tool is small relative to the other uncertainties that are inherent in this stage of the project. We plan to further map, analyze and quantify the uncertainties in order to test this hypothesis.

CONCLUSION

We have devised simple methods for assessing two key performance indicators for three general types of stormwater control measures commonly used in LID: permeable paving, bioretention units and local detention ponds. The methods are implemented in a tool that allows very rapid evaluation of the potential a given urban area has for LID retrofitting. In promising cases, more detailed models should consequently be used to refine the results. We are working on expanding the types of stormwater control measures included and on improving the user interface of the tool, in collaboration with end-user groups from different professions involved in LID planning.

REFERENCES

City of Copenhagen. 2011. “Climate Adaptation Plan.”

———. 2015. “Climate Change Adaptation and Investment Statement.”

Fletcher, Tim D., William Shuster, William F. Hunt, Richard Ashley, David Butler, Scott Arthur, Sam Trowsdale, et al. 2015. “SUDS, LID, BMPs, WSUD and More – The Evolution and Application of Terminology Surrounding Urban Drainage.” *Urban Water Journal* 12 (7): 525–42. doi:10.1080/1573062X.2014.916314.

Fratini, C F, Govert D Geldof, J. Kluck, and Peter Steen Mikkelsen. 2012. “Three Points Approach (3PA) for Urban Flood Risk Management: A Tool to Support Climate Change Adaptation through Transdisciplinarity and Multifunctionality.” *Urban Water Journal* 9 (5): 317–31. doi:10.1080/1573062X.2012.668913.

Gerdes, Justin. 2012. “What Copenhagen Can Teach Cities About Adapting To Climate Change - Forbes.” *Forbes*. http://onforb.es/SfKN88.

Henrichs, M., J. Langner, and M. Uhl. 2016. “Development of a Simplified Urban Water Balance Model (WABILA).” *Water Science and Technology*. doi:10.2166/wst.2016.020.

Index. 2013. “Danish Capital Adapts Successfully to Changing Climate.”

https://designtoimprovelife.dk/danish-capital-adapts-succesfully-to-changing-climate/.

Konkurrence og Forbrugerstyrelsen. 2015. “Vejledning Om Spildevandsselskabernes Medfinansiering Af Klimaprojekter.”

Lerer, Sara Maria, Karsten Arnbjerg-Nielsen, and Peter Steen Mikkelsen. 2015. “A Mapping of Tools for Informing Water Sensitive Urban Design Planning Decisions—Questions, Aspects and Context Sensitivity.” *Water* 7 (3): 993–1012. doi:10.3390/w7030993.

Sørup, Hjalte Jomo Danielsen, Sara Maria Lerer, Karsten Arnbjerg-Nielsen, Peter Steen Mikkelsen, and Martin Rygaard. n.d. “Efficiency of Stormwater Control Measures for Combined Sewer Retrofitting under Varying Rain Conditions : Quantifying the Three Points Approach (3PA).” *In Press*.