Development of Procedures for Holistic Planning of Sustainable Storm-water Management for Water Sensitive Cities

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Highlights

- Structured approach for planning future water sensitive cities was tested successfully
- Indexation of different analyses enables overlaying and visualization of the overall result
- Increase in evaporation & decrease in heat for LIDs needs to be examined in future work

Introduction

Planning of urban water infrastructure faces three major challenges: Spatially heterogeneous development of population and settlements, climate change and growing scarcity of resources (UNESCO 2019, World Bank Group 2018, DIFU 2017). On the other hand, the ongoing digitalization is often considered as a key to tackle these challenges (Lloyed Owen 2018, Ingildsen & Olsson 2016). The goal of the Indo-German research-project SMART&WISE is to improve planning processes for smart and reliable water and wastewater infrastructure systems facing these challenges. The project team dealt with the question of what is meant by a smart city when it comes to water infrastructures (Dilly et al. 2019, 2020). It has been concluded that a smart city does not necessarily have to be a digital city. Rather, it should be committed to the benefit of the citizens and it has to be sustainable in dealing with resources. Therefore, a holistic approach for a water sensitive city was developed. While dealing with stormwater management, the developed approach considers the flood risk, the impact on the water balance, the use of rainwater to mitigate water scarcity and measures to reduce heat islands. This article describes the holistic planning approaches for dealing with rainwater in water-sensitive cities.

Methodology

The approach is based on the idea that sustainable stormwater management should, on the one hand, guarantee the safe drainage of rainwater and, on the other hand, considers rainwater as a valuable water resource. Therefore, four analyses form the basis of the planning approach: (1) Flood Protection, (2) Water Balance, (3) Water Scarcity and (4) Heat Islands, as shown in Fig. 1. More details of the analyses are presented in flowcharts elsewhere (Dilly et al. in-press). When planning infrastructure systems, a distinction must be made between Retrofit and Greenfield Planning (Dilly et al. 2021). With the Retrofit approach, the need for action should be identified first by overlaying the results from the four analyses. For this purpose, results from each analysis are converted into index values, which indicate the need for action at any specified location. The index values from each of the analysis are then weighted and added. For the Greenfield Planning approach, it is recommended that the analyses are applied in a specific order, so that the intermediate results can be used for the next planning steps. In both cases, the measures implemented for achieving the goals include conventional structures and low impact development measures (LIDs: e.g. infiltration swales, green roofs). These measures should be planned in an iterative process, in which they are evaluated using the analyses during each iteration and subsequently improved upon. Although involvement of the decision-makers is not explicitly mentioned in figure 1, it is a prerequisite for the application. For example, weights for overlay of the individual analyses must be defined by the stakeholders. The developed procedure has been tested and evaluated for pilot cases in Germany and India.

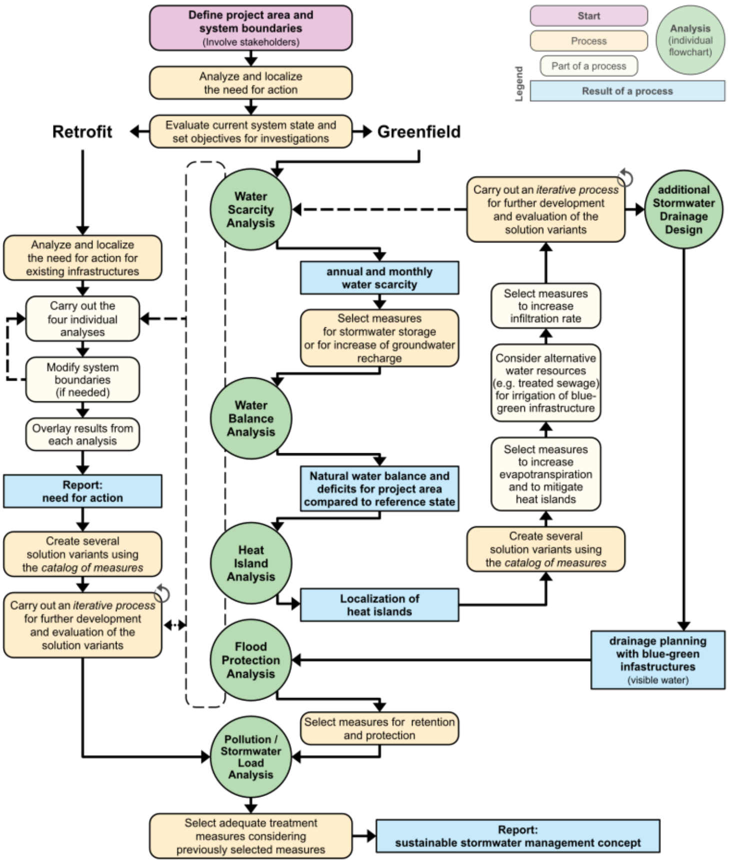

Figure 1. Structure of the holistic planning approach for stormwater management

Results and discussion

The results presented here focus on the retrofit approach. It was tested for the pilot case Ochsenhausen in Germany, where a functioning infrastructure already exists. Ochsenhausen is not affected by water shortages. Therefore, the water scarcity analysis was not considered further. Figure 2 shows the indexation created for the remaining three analyses, the resulting overlay and the corresponding holistic evaluation of the solution variants for one settlement unit.

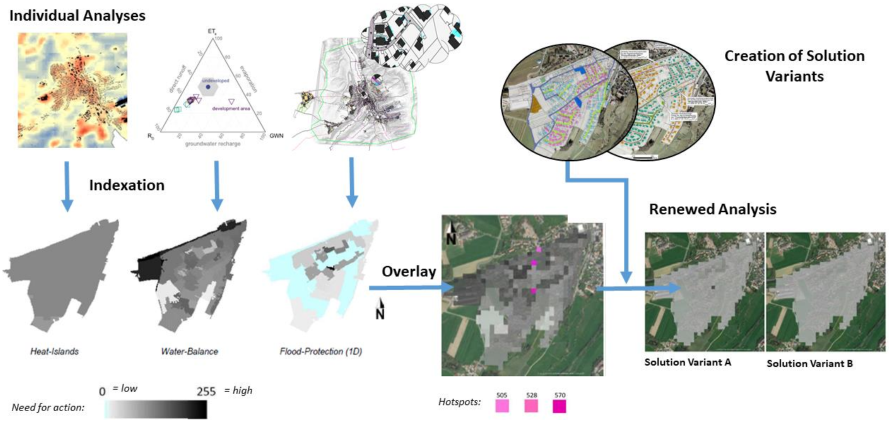

Figure 2. Overview of the test results of the holistic planning approach for the German pilot case

(1.) Landsat 8 OLI/TIRS temperature data and a vulnerability analysis were used as the basis for the heat island analysis. The temperature values, available as grid values, can easily be converted into index values. The indexation shows a moderate and uniform distribution. (2.) The water balance analysis was carried out using the software WABILA (Henrichs et al. 2016). It allows the determination of runoff, evaporation and infiltration depending on the specified surface and existing LIDs. In this process the natural water balance of a nearby undeveloped area is defined as the target state. The deviation from the target state was calculated for sub-areas with similar settlement structures and then converted into index values. (3.) On the basis of 1D, 2D and 1D/2D simulations of extreme rain events were carried out with the software ++SYSTEMS (tandler.com). On this basis areas prone to flooding by sewer overflow or direct surface runoff were identified. Manholes and conduits were associated with their catchment-areas. These areas got an index value in relation to the sewer overflow volume of the simulated flooding. (4.) The overlay was generated by adding up the three analyses results. (5.) To improve the overall situation, two possible solution variants with LIDs were created. Variant A considered measures only in public spaces (e.g. infiltration areas, swales and surface unsealing) while Variant B considered redesign of private properties (e.g. green roofs, cisterns, swales) as well. (6.) The solution variants were evaluated again. Although evaluation has not been carried out to determine the reduction of heat islands yet, the two solution variants show a clear improvement regarding urban flooding and the water balance parameters as compared to the current situation. The approach helps to combine the different tasks that can be tackled by rainwater sensitive city-development into one procedure.

Conclusions and future work

Following conclusions can be made from the work carried out so far:

- The developed holistic approach for planning a Sustainable Stormwater Management considering flooding, urban water balance and heat islands was successfully tested. The structured approach can facilitate interdisciplinary collaboration.
- Further research is required to develop appropriate models for reduction of the heat island effect by LIDs.
- The majority of LIDs greatly increase infiltration but their effect on evaporation seems to be small. The test has shown that the target condition "reaching the natural water balance" is therefore difficult to achieve. Additional research is needed to evaluate LIDs with respect to evaporation.
- In Germany the deviation from the natural water balance is used as an argument to support LIDs. However, this is not recommended in semi-arid or arid regions, as this further increase the water stress. Therefore, a balance between water sources, water storage, water reuse and water demand should be further explored.

Acknowledgments

Authors thank the master students Marvin Bruch, Philip Frankenberg, Michael Geyer and Sarah Zwanzger who were involved in testing the approach. This work was carried out as part of Indo-German research project SMART&WISE. The project was funded by the Indo-German Science & Technology Centre (IGSTC) established by the Department of Science and Technology (DST), Government of India and the Federal Ministry of Education and Research (BMBF).

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