Author Response to Referee #2

The potential of green infrastructure in urban pluvial flood mitigation - a scenario-based modelling study in Berlin

Sophia Dobkowitz et al.
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RC: ***Referee Comment***, AR: *Author Response*

Dear Referee,

thank you very much for your positive response, and for taking the time and effort to examine the manuscript.

Your comments are very helpful to clarify certain aspects in the manuscript and improve its quality. Please find a point-by-point reply below.

Kind regards,

Sophia Dobkowitz (on behalf of the author team)

Comments and responses

General comments:

RC: ***1. The methodological approach of working with different open source models (model chain) leads to inaccuracies in the model interfaces. How sensitive to results are these model interfaces, even if they represent a global boundary condition of the relative comparison?***

AR: We agree that the coupling of the different models leads to certain inaccuracies but this is rather due to the methodological framework of the model chain and not because the models are open source. Looking at each step of the model chain we can say

1. Rain input to SWMM: Here we do not expect uncertainties, as there is no physical feedback between hydrology and meteorology for short heavy rain events in the urban environment.
2. SWMM to TELEMAC: Here we expect an uncertainty, as there is interaction between hydrologic runoff formation and the hydrodynamic runoff concentration. This is especially relevant for the sewer network. Some research groups are recently working on the development of a bidirectional coupling of TELEMAC and SWMM.
3. TELEMAC to FlooDEsT: Theoretically it is possible, that at extreme flood conditions a building gets so heavily damaged that it is simply swept away. However, this is highly unlikely in a flat area with low

> water velocities. Furthermore, models capable of simulating such scenarios on a large scale are still the subject of active research

We will take into account this methodological limitation, which mainly concerns the interface of SWMM and TELEMAC. In the introduction, before specifying the research questions, we will add:

Our aim is not to present a fully calibrated flood model chain, but rather a framework for assessing green infrastructure (GI) effectivity.

RC: ***2. Simply taking into account the drainage contribution of the sewer system by reducing the effective precipitation is quite inaccurate. This also fails to take into account overflow effects from the sewer system to the surface. Since this cannot be quantified, it would be helpful at least to be discussed in greater detail.***

AR: In order to consider your concern about the simplified representation of the sewer system, we will add the following paragraph to the methods section 2.3.2 Conventional stormwater management:

This simplification does not allow to represent processes such as sewer overflow to the surface. We opted for this approach nevertheless, as the drainage system of our study area is not publicly available and the sewer system is not the focus of this study.

Specific comments

RC: ***1. p. 1, L3 (abstract): Flood risks cannot be reduced by the influence of evapotranspiration from BGI, as correctly stated on p8, L163 (contradiction)***

AR: Evapotranspiration is important to empty the storage after the rain event but does no reduce flood risk during the event. Consequently, we will remove it here.

RC: ***2. p. 3, L59: Neumann et al. 2024 do not describe the overflow frequencies of the CSO.***

AR: Maybe this formulation was not clear enough; we are not talking about combined sewer overflow (CSO) frequencies but volumes. In table 8, Neumann shows the sewer overflow volume for the different scenarios, which results in a sewer overflow reduction of 95 % for the described event. As the study area has a combined sewer system, this is CSO volume reduction. We will add "volume" to the sentence to make it more understandable:

CSO volume even decreased by 95 % for the same event.

RC: ***3. p. 7, L125: Citation of EN 752-2 by Sieker & Neidhart is not necessary (secondary reference)***

AR: We agree and will remove the reference.

RC: ***4. p. 7, L137: GR Soil layer > 1m is the exeption/very rare, not common.***

AR: That's true, such soil layers are not common. Consequently, we will remove it and just state that intensive GR have a soil layer of at least 12 cm.

RC: ***5. p. 8, L173: Depression storage of roads as a contribution to the sewer network ("gully absorption") is very inaccurate (see above). How high are the contributions in each case (please supplement Appendix A if necessary)?***

AR: As our simplified gully approach was applied only in the gully scenario, the contribution of this "gully absorption" can be seen very easily in Figure 3 and Table A1 by comparing gully to base scenarios and in

Figure 4. In order to avoid any confusion if the “gully absorption” might also be used in the GI scenarios, we will clarify this in table 2 (see answer to question RC1-7).

RC: ***6. p. 9, table 3: the berm height (surface layer) defines how quickly the BGI overflows and thus has a decisive effect on flood mitigation. Were any other values for berm height examined? It would be good to describe the sensitivity of this important parameter.***

AR: It is right that berm height is a very important GI parameter. For instance, we used for BR a berm height of 150 mm. In case of the 100-year event (50 mm), a decrease in berm height to 50 mm increases runoff by 42 %, while an increase in berm height to 200 or even 300 mm decreases runoff by 20 or 55 %, respectively. For the extreme event (100 mm), the differences in berm height matter less, with runoff increasing by 13 % with a berm height of 50 mm and decreasing by 6 or 18 % when increasing berm height to 200 or 300 mm, respectively. We decided for a berm height of 150 mm based on values from the literature gathered in Dobkowitz et al. (2025), (for further details on the GI parameters, see answer to question RC1-6).

Describing in detail the sensitivity of berm height would require to discuss also more parameter values and go beyond the scope of this study. However, we will include this topic by adding the following paragraph in the end of discussion section 4.1:

Besides the spatial extents of the GI scenarios, flood mitigation is sensitive to design parameters such as berm height and layer thickness, and their hydraulic parameters. These parameters were selected based on the literature as described in section 2.3.3 and we did not include more variations of each GI type, as the focus of this study is the comparison between different rain events and the propagation of the flood mitigation through the model chain. However, testing more parameter sets would allow to investigate if the comparison of different GI types is robust or too sensitive to the parameters.

RC: ***7. p. 10, L203ff: The building damage model is only briefly described with reference to Thieken et al. 2005. However, due to the complex boundary conditions, it can be assumed that it is subject to considerable uncertainty despite extensive modeling. This should be emphasized more clearly, even if the focus is on the relative comparison of the results. Important individual aspects that are not adequately considered are e.g. the lack of cadastral information on basements.***

AR: The model itself is referenced to Samprogna Mohor et al., 2015 (Line 197), whilst Thieken et al., 2005 (Line 206) gives further details about the input variables. We overcome the missing cadastral information by random sampling and use the average damage class as final result (as already stated in Line 210-212). Across the random sampling, despite some variation in the estimated damage degree, in 97 % of runs the estimations fell under the same damage class (low, medium, high, or very high), which indicates a robust result. For the damage model is by nature non-linear, a direct sensitivity analysis per predictor (e.g. basement) is not straightforward. We will add the following sentence to the manuscript: "After the random sampling process, despite some variation in the estimated damage degree, in 97 % of the runs the estimations fell under the same damage class (not shown), which indicates great stability of results."

RC: ***8. p. 11, L209, L232: In addition to water depth and flow velocity, the duration of exposure also has a major impact. The models and hazard maps only show the maximum amplitude of the flood. This is inaccurate for damage assessments.***

AR: Although duration is, strictly speaking, an influencing factor and could be relevant for a “universal” damage model for all flood types, duration was deemed not statistically significant while training the model specific for urban pluvial floods, which present overall events of shorter duration. The damage model FlooDEsT was developed specific for urban pluvial floods, which is also the application in this manuscript. We can reinforce that this is not a flaw of the Recursive Partitioning approach. Parallel damage model developments based partially on the same survey dataset but using different modelling families (Bayesian Regression - Mohor et al. 2021; Bayesian Network - Vogel et al 2018) similarly show low significance of Duration as a predictor for urban pluvial floods (therein labelled „surface water floods“).

RC: ***9. p. 17, table 4: The comparison with other studies is good and valuable. The other studies are cited and described only with a brief comment. However, where possible, it should be explained in more detail how the model boundary conditions differed in the other case studies in order to evaluate the deviations in the results more clearly.***

AR: We will add further information to the short presentation of the studies used to compare runoff retention:

- *Ercolani et al. (2018) used the model smart-green (MOBIDIC-U and a QGIS plugin) to investigate GR in a 1.9 km2 study area in Milan, Italy (MAP 800 mm). The GR is composed of a 200 mm soil layer and a 150 mm drainage mat.*
- *Fu et al. (2020) coupled SWMM and Hydrus-1D to model PP in a 3.3 km2 study area in Xiamen, China (MAP 1413 mm). Below the permeable brick layer with a thickness of 60 mm, there are 4 different permeable layers with in total 940 mm.*
- *Hua et al. (2020) also studied PP, using the model MIKE URBAN for a 7.4 km2 study area in Chaohu, China (MAP 1307 mm). In this study, the pavement layer is 120–180 mm, underlain by 300 mm of permeable material.*
- *Peng et al. (2019) investigated GR with SWMM in a 0.044 km2 study area in Fuzhou, China (MAP 1500 mm). The GR has a berm height of 15 mm, a soil layer thickness of 150 mm and a drainage mat of 30 mm.*
- *Schlea et al. (2014) investigated BR with an experimental study, using a rain gauge, graduaded containers for runoff and drainage measurements and piezometers for water table changes. This setup was used in a 869 m2 study area located in Westerville, USA (MAP 1105 mm). The layer thicknesses were not reported in the study.*
- *Zhang et al. (2020) modeled BR with SWMM in a 6.07 km2 study are in Kyoto, Japan (MAP 1677 mm). The BR has a berm height of 150 mm, soil layer thickness of 700 mm and a storage layer of 300 mm.*

RC: ***10. p. 21-23, Appendix A, table A1: How are the building damage categories (“low” - “very high”) quantified and categorized? Are they corresponding to the max. water level?***

AR: Thank you for pointing out, we have not defined the damage categories in the manuscript. The damage categories are a split of the relative damage (see answer to question RC1-14).

A direct relationship between damage and each predictor variable is hard to plot or define, as the model is by nature non-linear. All predictors interplay in estimating the relative damage and thus the damage categories.

We will add the following explanation of damage classes to the methods section about the building damage model:

Building damage classes, based on the relative building damage: Low: 0–5 %. Medium: 5–10 %. High: 10–15 %. Very High: 15–100 %.

References

Ercolani, G., Chiaradia, E. A., Gandolfi, C., Castelli, F., and Masseroni, D.: Evaluating performances of green roofs for stormwater runoff mitigation in a high flood risk urban catchment, Journal of Hydrology, 566, 830–845, 2018.

Fu, X., Liu, J., Shao, W., Mei, C., Wang, D., and Yan, W.: Evaluation of permeable brick pavement on the reduction of stormwater runoff using a coupled hydrological model, Water, 12, 2821, 2020.

Hua, P., Yang,W., Qi, X., Jiang, S., Xie, J., Gu, X., Li, H., Zhang, J., and Krebs, P.: Evaluating the effect of urban flooding reduction strategies in response to design rainfall and low impact development, Journal of cleaner production, 242, 118 515, 2020.

Mohor, G. S., Thieken, A. H., and Korup, O.: Residential flood loss estimated from Bayesian multilevel models, Nat. Hazards Earth Syst. Sci., 21, 1599–1614, https://doi.org/10.5194/nhess-21-1599-2021, 2021.

Peng, Z., Jinyan, K., Wenbin, P., Xin, Z., and Yuanbin, C.: Effects of Low-Impact Development on Urban Rainfall Runoff under Different Rainfall Characteristics, Polish Journal of Environmental Studies, 28, 2019.

Schlea, D., Martin, J. F., Ward, A. D., Brown, L. C., and Suter, S. A.: Performance and water table responses of retrofit rain gardens, Journal of Hydrologic Engineering, 19, 05014 002, 2014.

Vogel, K., Weise, L., Schröter, K., and Thieken, A. H.: Identifying driving factors in flood-damaging processes using graphical models. Water Resources Research, 54, 8864–8889. https://doi.org/10.1029/2018WR022858, 2018.

Zhang, L., Ye, Z., and Shibata, S.: Assessment of rain garden effects for the management of urban storm runoff in Japan, Sustainability, 12, 9982, 2020.