Impacts of future climate change on urban flood risks: benefits of climate mitigation and adaptations [MS No.: hess-2016-369]

Responses to review comments

Anonymous Referee #2:

SHORT COMMENTS IN THE JOURNAL STYLE Scientific questions:
Adaptation effects on drainage performance in a context of climate change (CC) is relevant. Novel concepts. Try to quantify the impact adaptation measures is potentially new if appropriately developed in single case studies. Substantial conclusions. Not attended yet, due to insufficiently explained datasets and methods. Scientific methods and assumptions. Not clearly outlined. Results vs interpretations / conclusions. Unattended. Description. Pretty obscure. Authors proper credit. Ok! but not all is new. Title. OK! but to be revised in case of revision. Summary. Unbalanced on Climate trends when the most interesting part is adaptation. Overall presentation. Lacking of context outline. Language. To be revised by a mother tongue, that I am not. Formulae. Not expert enough to say. Parts to modify. Develop 1, 4 & 5, Clarify 2a & 2e, Reduce 2b, Delete 3b, Modify Fig. 1 & 5. References. Ok.

Response: *We greatly appreciate the reviewer for the constructive comments and suggestions to improve our manuscript. In the revision, we have 1) added more details on the datasets and methods, 2) added more discussions on the assumptions and limitations, 3) modified the relevant statements and figures which are unclear or inaccurate, 4) revised the specific sections as suggested, 5) invited a native speaker to proof-read the paper. More details of our responses to each comment are provided as follows.*

EXTENDED COMMENTS
1 Introduction All key definitions should be provided here. Flood risk is the probability an hazard has to generate damages (UNISDR, ISO etc: : :), not a probability of a disastrous flood only (that is hazard occurrence). Should be wise to specify to whom this work is addressed, since very essential information of the case study is missing (see next sections).

Response: *Thanks for the comments. We agree with the reviewer that flood risk refers to the probability of a hazard to cause damage. In this study, we investigate the potential changes in flood volume (TFV) under various scenarios of climate changes and explore the role of adaptations in regulating such changes. We acknowledge that the TFV is a hazard indicator, while flood damage is tightly linked to socio-economic conditions which is not addressed in this study. We have clarified this concept in the revision.*

This study investigates the performance of drainage system under climate change scenarios, which has great implications for adaptation and mitigation strategies in a typical city in Northern China. Comparing the reduction of flood volume by climate mitigations (via reduction of greenhouse gas emissions) and local adaptations (via improvement of the drainage system) indicates that local adaptations are more effective than climate mitigations in reducing future flood volumes. This has broad implications for the research community on drainage system design and modeling in a changing environment. We emphasize the importance of considering adaptions in assessing climate change impacts on future urban floods. In the revision, we have provided more detailed information on the case study region, research background and the implications following the suggestions.

2. Material and Methods 2a) (i) A characterization of the hazard (rainfall) in Hohhot City is missing.
Response*: Thanks for the comments. In the study region, most of rain storms fall between June and August, which accounts for more than 65% of annual precipitations. In the revision, we have provided more descriptions on the rainfall characterizations and flood hazards in the study region.*

It should be noted that the input rainfall time series for the model are not the original historical observations. Rather, it is based on the storm intensity formula (SIF), which is used to estimate the design rainfall for each return period. The modeling practice mainly follows the standard procedure in urban drainage modeling in China, as documented in the national code for design of outdoor wastewater engineering (MOHURD, 2011). Specifically, the SIF represents an Intensity-Duration-Frequency (IDF) relationship, and is commonly used in the literature to estimate design rainfall hydrographs (Berggren et al., 2014; Cheng and AghaKouchak, 2014; Panthou et al., 2014; Willems, 2000; Zhou et al., 2012). Subsequently, the Chicago Design Storms (CDS) approach is applied to derive the design storms from the local SIF for the SWMM model as used in this study. The detailed procedures in using SIF to obtain the CDS design storms can be found in Chinese National Technical Guidelines for Establishment of Intensity-Duration-Frequency Curve and Design Rainstorm Profile (MOHURD, 2014) and have been well adopted in a number of Chinese urban drainage designs (Wu et al., 2016;Yin et al., 2016; Zhang et al., 2008; Zhang et al., 2015).

For the case study, the local rainfall is characterized by the SIF ($q=635*(1+0.841*lg(P))/t^{0.61}$), which is obtained from local weather bureau. 10 return periods are considered in the paper and a 4-hour rainfall time series is generated for each return period at a 10-minute interval. The technical details in using SIF to derive the CDS rainfall are given in the following. As shown in the Equation 1, the q is the average rainfall intensity, t is the storm duration and P is the design return period. The typical temporal

resolution considered in SIF for urban drainage simulations is minutes. A, b, c and D are regional parameters governing the IDF relations among rainfall intensity, return period and storm duration. For a given return period, the SIF is fitted into the Horner's equation as Eq.2:

$$q = \frac{A(1 + Dlg(P))}{(t + b)^c} \qquad \text{Eq. (1)}$$

$$i = \frac{a}{(t + b)^c} \qquad \text{Eq. (2)}$$

The synthetic hyetograph based on the Chicago method is computed using Eq. 2 and an additional parameter r (where 0< r <1) which determines the relative location of peak intensity (with respect to time), $t_p=r*t$. The time distribution of rainfall intensity is described after the peak $t_a = (1-r)*t$ and before the peak $t_b=r*t$ by Eq. (3) and (4). i_b is the instantaneous rainfall intensity before the peak , i_a is the instantaneous rainfall intensity after the peak.

$$i_a = \frac{a[\frac{(1-c)t_a}{(1-r)} + b]}{(\frac{t_a}{(1-r)} + b)^{1+c}} \qquad \text{Eq. (3)}$$

$$i_b = \frac{a[\frac{(1-c)t_b}{r} + b]}{(\frac{t_b}{r} + b)^{1+c}} \qquad \text{Eq. (4)}$$

By following the above procedure, a 4-hour rainfall time series can be generated for each return period with the peak located in the center of the period. In the revision, we have added more details about the rainfall and methods.

Reference:

Berggren, K., Packman, J., Ashley, R., and Viklander, M.: Climate changed rainfalls for urban drainage capacity assessment, Urban Water Journal, 11, 543-556, 10.1080/1573062X.2013.851709, 2014.

Cheng, L. Y., and AghaKouchak, A.: Nonstationary Precipitation Intensity-Duration-Frequency Curves for Infrastructure Design in a Changing Climate, Scientic Report, 4, 10.1038/srep07093, 2014.

MOHURD: AQSIQ. Code for Design of Outdoor Wastewater Engineering (GB 50014-2006), Ministry of Housing and Urban-Rural Development, General Administration of Quality Supervision, Inspection and Quarantine of the People's Republic of China: Beijing, China (In Chinese), 2011.

MOHURD: Technical Guidelines for Establishment of Intensity-Duration-Frequency Curve and Design Rainstorm Profile (In Chinese), Ministry of Housing and Urban-Rural Development of the People's

Republic of China and China Meteorological Administration. Accessed on November 2016 from http://www.mohurd.gov.cn/wjfb/201405/W020140519104225.pdf, 2014.

Panthou, G., Vischel, T., Lebel, T., Quantin, G., and Molinie, G.: Characterising the space-time structure of rainfall in the Sahel with a view to estimating IDAF curves, Hydrology and Earth System Sciences, 18, 5093-5107, 10.5194/hess-18-5093-2014, 2014.

Willems, P.: Compound intensity/duration/frequency-relationships of extreme precipitation for two seasons and two storm types, Journal of Hydrology, 233, 189-205, http://dx.doi.org/10.1016/S0022-1694(00)00233-X, 2000.

Wu, H., Huang, G., Meng, Q., Zhang, M., and Li, L.: Deep Tunnel for Regulating Combined Sewer Overflow Pollution and Flood Disaster: A Case Study in Guangzhou City, China, Water, 8, 329, 2016.

Yin, J., Yu, D. P., Yin, Z., Liu, M., and He, Q.: Evaluating the impact and risk of pluvial flash flood on intra-urban road network: A case study in the city center of Shanghai, China, Journal of Hydrology, 537, 138-145, 10.1016/j.jhydrol.2016.03.037, 2016.

Zhang, Y.-q., Lv, M., and Wang, Q.-g.: Formula method design of drainage pipe network and analysis of model simulation, Water Resource Power, 33, 105-107, 2015.

Zhang, D., Zhao, D. q., Chen, J. n., and Wang, H. z.: Application of Chicago approach in urban drainage network modeling, Water & Wastewater Engineering, 34, 354-357, 2008.

Zhou, Q., Mikkelsen, P. S., Halsnaes, K., and Arnbjerg-Nielsen, K.: Framework for economic pluvial flood risk assessment considering climate change effects and adaptation benefits, Journal of Hydrology, 414, 539-549, 10.1016/j.jhydrol.2011.11.031, 2012.

(ii) A detailed description of watershed soils is recommended. Rocky, lateritic, clay, sandy, or: : : soils perform differently in semi-arid contexts than in wet contexts. Even where infiltration seems possible some pervious looking soils after the first minutes turn into impervious. Context matter in this type of study.

Response*: Thanks for the comments. We agree with the reviewer that soil conditions matter in this type of study. In this study, three general soil categories are considered, i.e., the sand, loam and clay. According to the limited data on local soil conditions from local water authorities, the major soil type of the study region is a mixture of loam and clay. Based on the Horton's infiltration method (Rossman and Huber, 2016) and the values suggested by (Akan, 1993) as shown in the table below, we used the values under the category of "Dry loam soils with little or no vegetation" to represent the maximum infiltration capacity in the model. We have added more descriptions on this in the revision.*

Maximum (Initial) Infiltration Capacity (Akan, 1993)		
Soil Type	*(in/hr)*	*(mm/hr)*

|		
Dry sandy soils with little or no vegetation	5.0	127
Dry loam soils with little or no vegetation	3.0	76.2
Dry clay soils with little or no vegetation	1.0	25.4
Dry sandy soils with dense vegetation	10.0	254
Dry loam soils with dense vegetation	6.0	152
Dry clay soils with dense vegetation	2.0	51
Moist sandy soils with little or no vegetation	1.7	43
Moist loam soils with little or no vegetation	1.0	25
Moist clay soils with little or no vegetation	0.3	7.6
Moist sandy soils with dense vegetation	3.3	84
Moist loam soils with dense vegetation	2.0	5.1
Moist clay soils with dense or no vegetation	0.7	18

To further address the concern, we have conducted a set of sensitivity experiments in the revision. Specially, we used three possible infiltration values corresponding to the first three soil types (i.e., dry sand, loam and clay soils with little or no vegetation) as listed in the above table. The parameters associated with each possible infiltration value are shown in the table below:

| **Infiltration parameters***	*MaxRate*	*MinRate*	*Decay rate*	*DryTime*
	[in/hr]	*[in/hr]*	*[1/hr]*	*[days]*
Dry loam with little or no vegetation	*3*	*0.5*	*4*	*7*
Dry sand with little or no vegetation	*5*	*0.7*	*5*	*5*
Dry clay with little or no vegetation	*1*	*0.3*	*3*	*9*
* To describe Horton infiltration method in SWMM, four basic infiltration parameters are required (Rossman and Huber, 2016) : • *MaxRate: Maximum infiltration rate on Horton curve* • *MinRate: Minimum infiltration rate on Horton curve* • *Decay: Decay rate constant of Horton curve* • *DryTime: Time it takes for fully saturated soil to dry*				

The original Figure 7 shows the comparison of benefits of climate mitigation and two adaptation strategies in reducing flood volume, based on the soil category 'Dry loam with little or no vegetation'. Here, we re-plotted the figure to show the uncertainty range arising from the representation of soil conditions in the drainage model, using the possible infiltration values of the aforementioned three categories. It is shown that magnitudes of estimated benefits differ to some degree, but the performance of adaptation measures is better than that of climate mitigation, which is supportive of the major conclusion of this study. We have included the relevant descriptions and results in the revised manuscript.
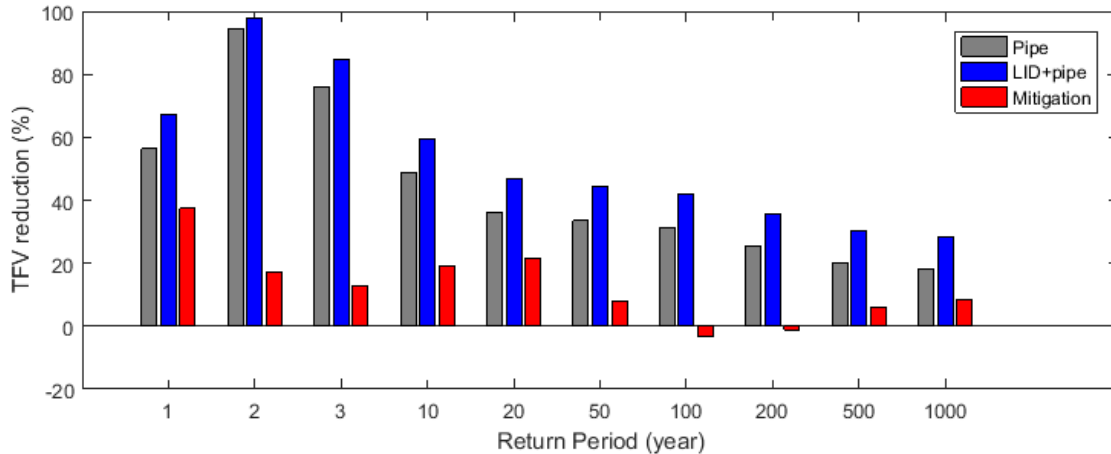
Original Figure 7 *Comparison of benefits of climate mitigation and two adaptation strategies in reducing urban floods with changes in precipitation intensities at various return periods.*
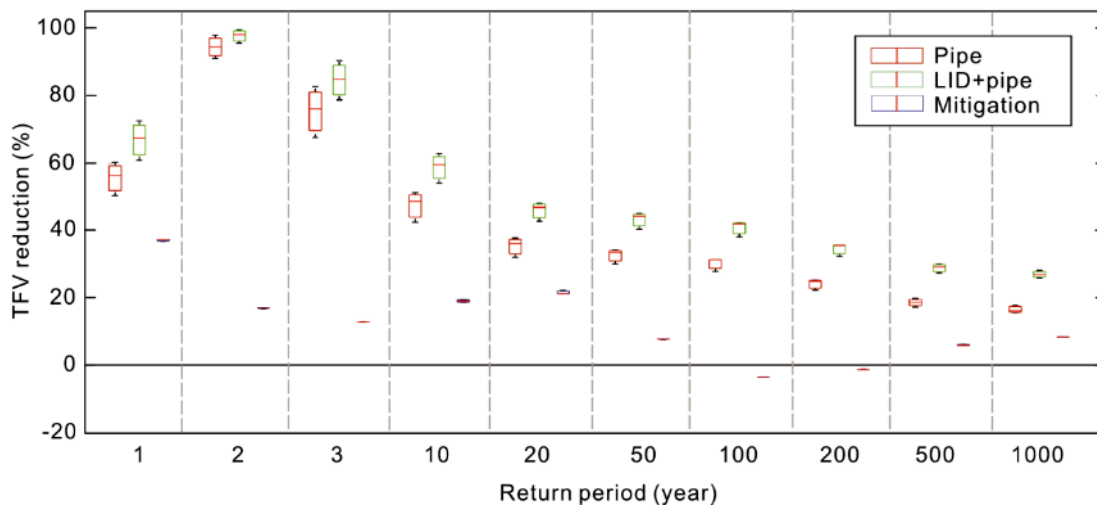

Revised Figure 7_with uncertainty: *Estimated benefits of climate mitigation and two adaptation strategies in reducing urban floods risks with changes in precipitation intensities at various return periods. Infiltration values corresponding to three soil categories are used and the boxplot is used to show the uncertainties arising from soil conditions.*

References:

Akan, O. A.: Urban stormwater hydrology: a guide to engineering calculations, CRC Press, 1993.

Rossman, L., and Huber, W.: Storm Water Management Model Reference Manual EPA/600/R-15/162A, 2016.

(iii) Authors consider permeable pavements, infiltration trenches and green roofs as possible adaptation measures. Which are the permeable soil and coverage rates in the different parts of the watershed considered?

Response*: Thanks for the comments. We agree that explicit consideration of permeable pavements, infiltration trenches and green roofs would make the designed adaptation measures more specific and realistic (Elliott and Trowsdale, 2007; Zoppou, 2001). However, there is no such detailed information on the permeable soil and coverage rates in the study region, which prevents us from representing these individual features/parameters in the model. Instead, the second adaptation scenario is designed to investigate the effects of increased permeable surfaces on flood volume, and is reflective of the combined effects of infiltration-related measures, including permeable pavements, infiltration trenches and green roofs. That is, a simplified approach by altering the subcatchment imperviousness was adopted due to the limitation of data availability in the study region. Specifically, we derived such information by comparing the current and planned landuse maps and incorporated the changes in landuse and imperviousness (see the updated Figure 1d) in the adaptation scenario. The figure 1d shows the difference in weighted mean imperviousness (WMI) calculated for each subcatchments (different parts of the watersheds) in the current and planned maps, which is used to indicate the areas that are more suitable for adaptation measures based on the city plan. For example, a subcatchment with a higher positive change in the WMI indicates that the area is planned to have a landuse type with lower imperviousness and therefore is assumed to be more suitable for lid planning, and vice versa. We have clarified this with more discussions in the revision.*
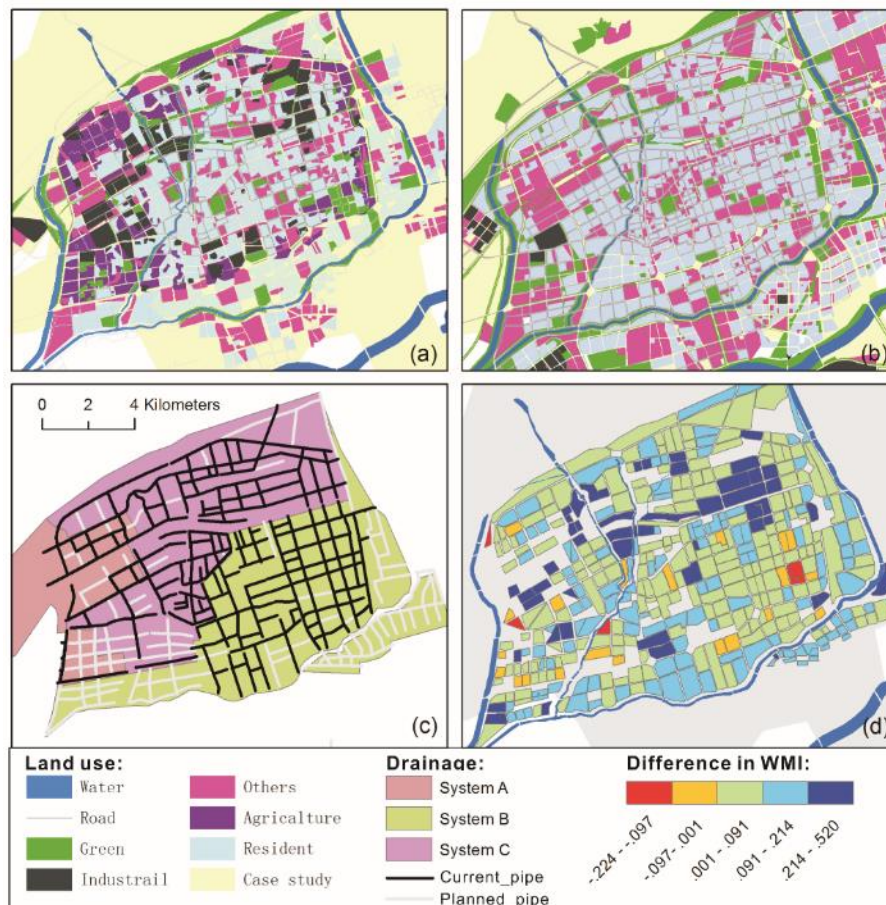
(iv) Can the authors provide some information about last disastrous floods in the case study? Areas affected the most, etc.

Response: *Thanks for the comment. On 11th July 2016, the city, especially the western part of the watershed, was hit by an extreme rainfall event with more than 100 mm of rain within 3 hours. The local meteorological department issued the red warning of rainstorm. Floods were reported in multiple sites in the central area and caused severe traffic jams in major streets (see the photos below). Some residential buildings were also flooded. The rain forced cancellations of at least 8 flights and 17trains, and delays of dozens of transportation systems. We have added more descriptions on this in the introduction of the study region in the revision.*

(Photos: yjhlnews.com(left) and chinanews.com(right))

To provide more background information on historical flood events in the study area, we have included a map describing historical flood records and city traffic network in Figure 5a. It is obvious that the central portion of the city is the most affected region due to the low service level of its drainage system. We have updated the Figure 5 and added more descriptions in the revised manuscript.
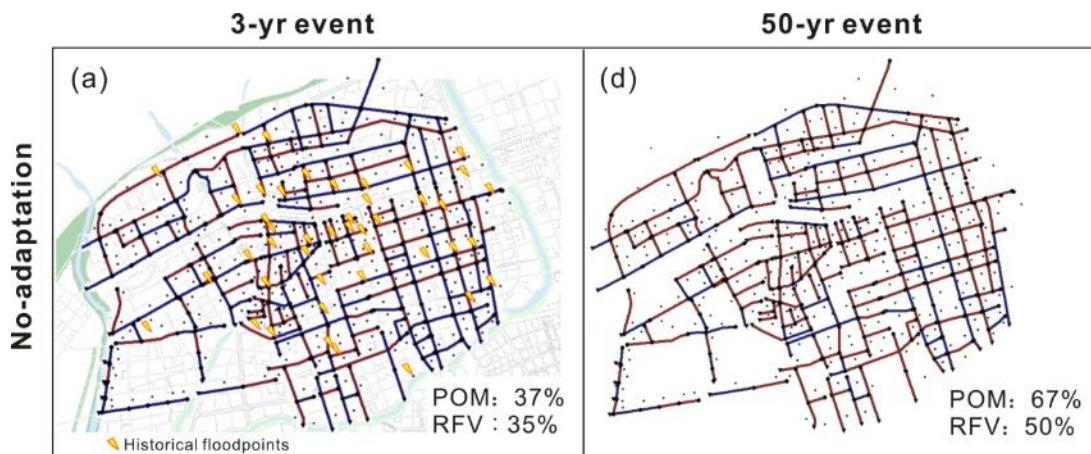

Figure 5*: Spatial distribution of overloaded pipelines (red colour) induced by the current 3-yr (left column) and 50-yr extreme events (right column) without and with adaptations. The total percentage of overloaded*

manholes (POM) and ratio of flood volume (RFV) are summarized. A summary of historical flood points are given in (a).

2b) (i) It's quite normal to use more than one GCMs .

Response*: Agreed. We have deleted relevant statements in the revision.*

(ii) Reader expects to learn from the expected changes in rainfall (mm and in which month) but no information is provided on this topic.

Response*: Thanks for the comments. Readers can refer to the table 1 which summarizes the changes in extreme precipitation intensity of various return periods. In the revision, we have added additional statistics on the monthly and annual precipitation changes.*

2c) (i) Which rainfall information has been used to run SWMM [dataset length (years) and type (daily, three hourly, hourly, etc.)]?

Response*: Thanks for the comments. The rainfalls as inputs for the model are based on artificial rains in the format of Chicago Design storms derived from historical rainfall records following the standard by the local weather bureau and the national code for design of outdoor wastewater engineering (please see response to comment 2a for details). The rainfall period is 4 hours at sub-hour (i.e., 10 minute) time step.*

2e) (i) The adaptation measures considered are to reduce the amount of water that run off. This is one side of the problem. The other one is to slow down the water speed. And for this no measure is considered: there is a wide range of measures for semi-arid contexts commonly used for this. I recommend to consider it or explain why you don't.

Response*: Thanks for the comments. We agree that slowing down the water speed could be an alternative adaptation approach for attenuating runoff peak and reducing flood volume (Messner et al., 2006; Floodsite, 2009). We note that the water speed is influenced by, among others, the gradient and flow resistance of the bed of the water course (Ashley et al., 2007) and such information is not available at the sub-catchment scale in the study region.*

There are two main reasons that we did not consider the measures by attenuating the water speed in our designed adaptation approach. First of fall, although some of the LID measures are primarily designed to slow down the flow speed, i.e., vegetated swales, most of the LID measures can reduce both runoff volume and flow speed at the same time. Constrained by the one-dimensional SWMM modelling approach in this study, the performances of LID measures are mainly evaluated according to their effects on reducing water volume from overloaded manholes (Oraei Zare et al., 2012;Lee et al., 2013). And it is difficult to examine

whether a reduced flood event for each manhole is induced by the runoff volume or inherent speed control function in the model. Second, there is a lack of data for us to consider and validate this specific measure in the case study. Especially, the required information on surface roughness, soil conductivity, seepage rate are unavailable at the subcatchment scale in the study region. Based on the available datasets on current and future landuse maps, this study tends to apply and assess adaptation measures that mainly affect the surface imperviousness. We have added the discussions in the revised manuscript.

Reference:

Ashley, R., Garvin, S., Pasche, E., Vassilopoulos, A., and Zevenbergen, C.: Advances in Urban Flood Management, in, edited by: Ashley, R., Garvin, S., Pasche, E., Vassilopoulos, A., and Zevenbergen, C., Taylor & Francis/Balkema, London, UK, 2007.

Floodsite: Flood risk assessment and flood risk management. An introduction and guidance based on experiences and findings of FLOODsite (an EU-funded Integrated Project), Deltares/Delft Hydraulics. ISBN 978 90 8 |4067|0, 2009.

Lee, J. M., Hyun, K. H., and Choi, J. S.: Analysis of the impact of low impact development on runoff from a new district in Korea, Water Science and Technology, 68, 1315-1321, 10.2166/wst.2013.346, 2013.

Messner, F., Penning-Rowsell, E., Green, C., Meyer, V., Tunstall, S., and Van der Veen, A.: Guidelines for Socio-economic Flood Damage Evaluation, Report Nr. T9-06-01, in, FLOOD site, HR Wallingford, UK, 2006.

Oraei Zare, S., Saghafian, B., Shamsai, A., and Nazif, S.: Multi-objective optimization using evolutionary algorithms for qualitative and quantitative control of urban runoff, Hydrol. Earth Syst. Sci. Discuss., 9, 777-817, 10.5194/hessd-9-777-2012, 2012.

(ii) How Authors have determined the impact of individual adaptation measures (permeable pavements, trenches, green roof) over run off reduction? This should be explained.

Response: *Thanks for the comments. As clarified in the response to 2a (iii), the second adaptation measure is mainly designed to investigate the impacts of increased permeable surfaces on flood volume reductions by altering the imperviousness of subcatchments to represent the infiltrated and detained water volume in the runoff-generation process. That is, the individual measures related to permeable pavements, trenches, green roof are not considered separately but represented in a combined and simplified approach. Thus, we are not able to explicitly assess the performance of these individual measures on flood reductions in details. We have added discussions on this in the revision.*

3) Results 3b) (i) I don't understand the approach: Mitigation is expected to impact on CC at long term (decades: : :). Drainage system is expected to reduce CC impacts at short-medium term (1-5 years). Is obvious that adapting we can't expect to see effects on rainfall: : :

Response: *Thanks for the comments. Mitigation refers to climate mitigations via reduction of greenhouse gas emissions. The mitigation effects are assessed here by comparing the results based on RCP8.5 emission scenario (which is a business-as-usual scenario) and RCP2.6 scenario (which considers the reduction of greenhouse gas emission). Climate mitigation via reducing greenhouse gas emissions is expected to influence precipitation characteristics and thus the subsequent flood hazards (i.e., flood volume in this study). Adaptation measures are localized and here refer to the specific design/update of drainage system. The possible land surface-atmosphere interactions which would indirectly affect the rainfall and floods are not considered in this study. We have clarified this in the revised manuscript.*

4) Uncertainties & Limitations (i) The consideration of the state of drainage system could be a limitation of this study? A drainage system obstructed by vegetation, waste or artefacts (cables, pipes, temporary constructions) can make the outcomes of the SWMM quite distant from the real world. And change also recommendations: : : that need to be extended to waste sector.

Response: *Thanks for the comments. We agree with the reviewer that the state of drainage system could affect its conveyance capacity and thus the system performance to various degrees. In some cases, floods are not induced by the exceedance of drainage capacity, but by the deterioration of drainage system itself, e.g., aging network, pipe deterioration, blockage, construction failures and local external factors (Dawson et al., 2008; CIRIA, 1997; Davies et al., 2001). Previous studies with a focus on sewer inspection and condition assessment, maintenance and rehabilitation strategies, have highlighted the need for labor-intensive field investigations for collecting information on the waste status and relocations, and such studies are often limited to certain areas (Ana and Bauwens, 2007; Fenner, 2000). In fact, assessment of drainage conditions requires detailed datasets, which has been recognized as a great challenge in applications. For example, in Europe, water service data collections mainly cover pipe length, age, material, diameter and location (Stone et al., 2002; Ana and Bauwens, 2007), while the assessment of pipe conditions are often managed by separate and specialized programs.*

It is beyond the scope of this study to take into account the actual state of the pipe system due to difficulties in collecting field data and selecting and utilizing appropriate methods for reasonable assessment of the current pipe conditions. Such studies usually require comprehensive efforts on the material, data and method, (e.g., Dawson et al. 2008; Chae and Abraham 2001; Chughtai and Zayed 2008), which is not the focus of this paper. We acknowledge that the hydraulic performance may be overestimated without considering the drainage conditions and the waste section in the SWMM modeling approach (Pollert et al., 2005). In the revision, we have added more discussions on the impacts of pipe conditions on system performance, which should be addressed in the future study.

References:

Ana, E., and Bauwens, W.: Sewer network asset management decision-support tools: a review, International Symposium on New Directions in Urban Water Management, 2007, 1-8, 12-14 September 2007, UNESCO Paris

Chae, M., and Abraham, D.: Neuro-fuzzy approaches for sanitary sewer pipeline condition assessment, J. Comput. Civ. Eng., 15, 4, 2001.

Chughtai, F., and Zayed, T.: Infrastructure Condition Prediction Models for Sustainable Sewer Pipelines, Journal of Performance of Constructed Facilities, 22, doi:10.1061/(ASCE)0887-3828(2008)22:5(333), 2008.

CIRIA: Risk Management for Real Time Control in Urban Drainage Systems: Scoping Study, Project Report 45. CIRIA, London., 1997.

Davies, J. P., Clarke, B. A., Whiter, J. T., and Cunningham, R. J.: Factors influencing the structural deterioration and collapse of rigid sewer pipes, Urban Water, 3, 73-89, http://dx.doi.org/10.1016/S1462-0758(01)00017-6, 2001.

Dawson, R. J., Speight, L., Hall, J. W., Djordjevic, S., Savic, D., and Leandro, J.: Attribution of flood risk in urban areas, Journal of Hydroinformatics, 10, 275-288, 2008.

Fenner, R. A.: Approaches to sewer maintenance: a review, Urban Water, 2, 343-356, http://dx.doi.org/10.1016/S1462-0758(00)00065-0, 2000.

Pollert, J., Ugarelli, R., Saegrov, S., Schilling, W., and Di Federico, V.: The hydraulic capacity of deteriorating sewer systems, Water Science and Technology, 52, 207-214, 2005.

Stone, S., Dzuray, E. J., Meisegeier, D., Dahlborg, A. S., and Erickson, M.: Decision-Support Tools for Predicting the Performance of Water Distribution and Wastewater Collection Systems., US EPA. 97pp., 2002.

5. Could the Authors consider to show us what is their way forward?

Response: *Thanks for the comments. As demonstrated in this study, adaptation is found to be more effective in reducing future flood volumes than climate mitigations. However, several simplified approaches were adopted in the modeling and assessments as commented by the reviewer. Depending on the progress on data collection and needs of local authorities, we plan to conduct a more comprehensive analysis of the adaptation measures in a more localized area by applying more advanced methods for pipe assessment (e.g., considering the changing pipe condition), LID measures (detailed modeling of LID control), two-dimensional surface flooding for the assessment of flood damage and risk, and those interesting points as raised by the reviewer. We have added discussions on this in the revision.*

Figures 1 & 5: scale is not showed: how large are blocs contoured by drainage network?

Response: *Thanks for the comments. In the revision, relevant figures have been updated by including a scale bar (see the attached figures below).*
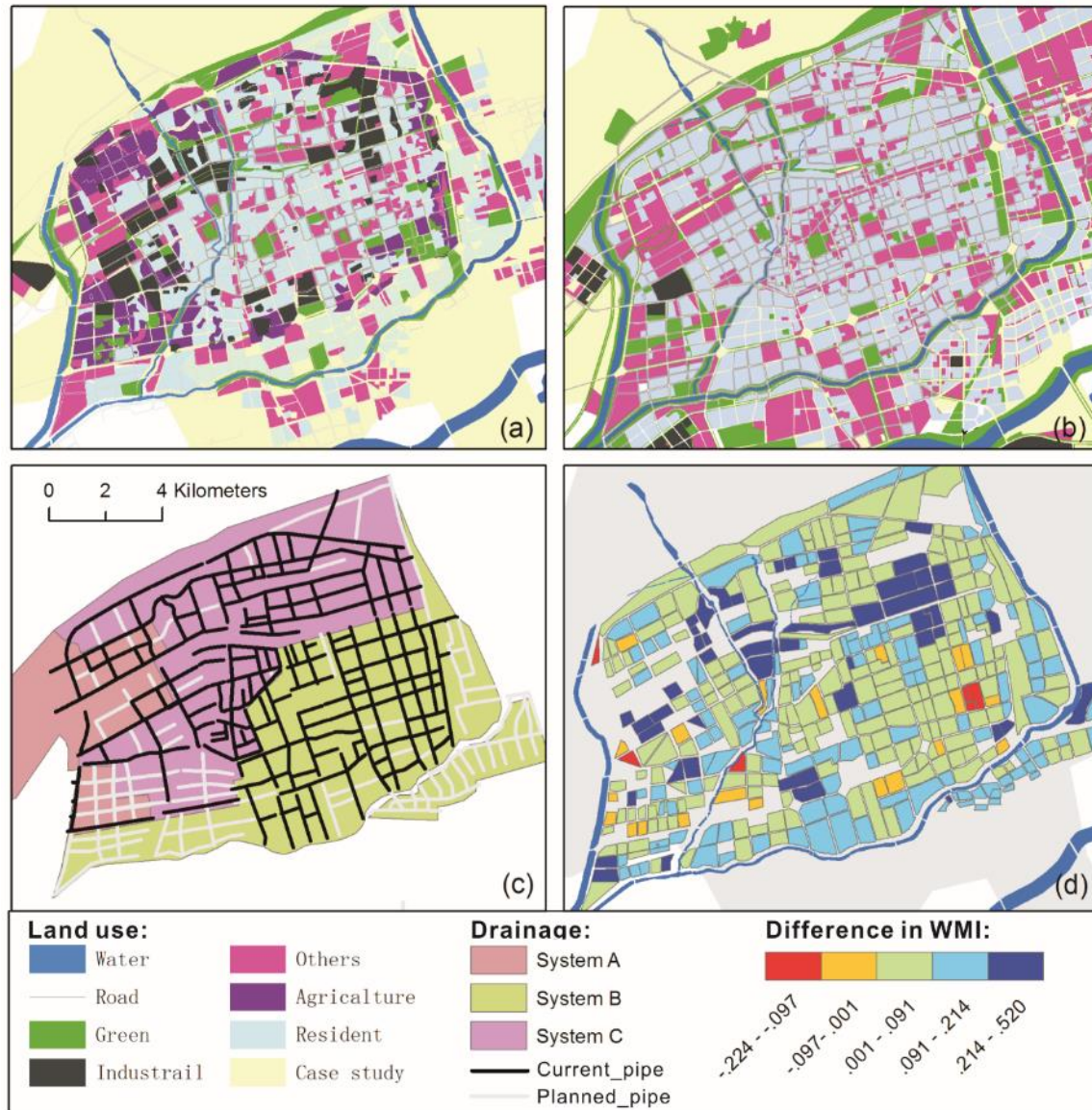
Figure 1 *Land use of the study region for the year 2010 (a) and 2020 (b). Pipe network description of current and planned drainage systems (c). Difference in Weighted Mean Imperviousness (WMI) between year 2010 and 2020 (d).*
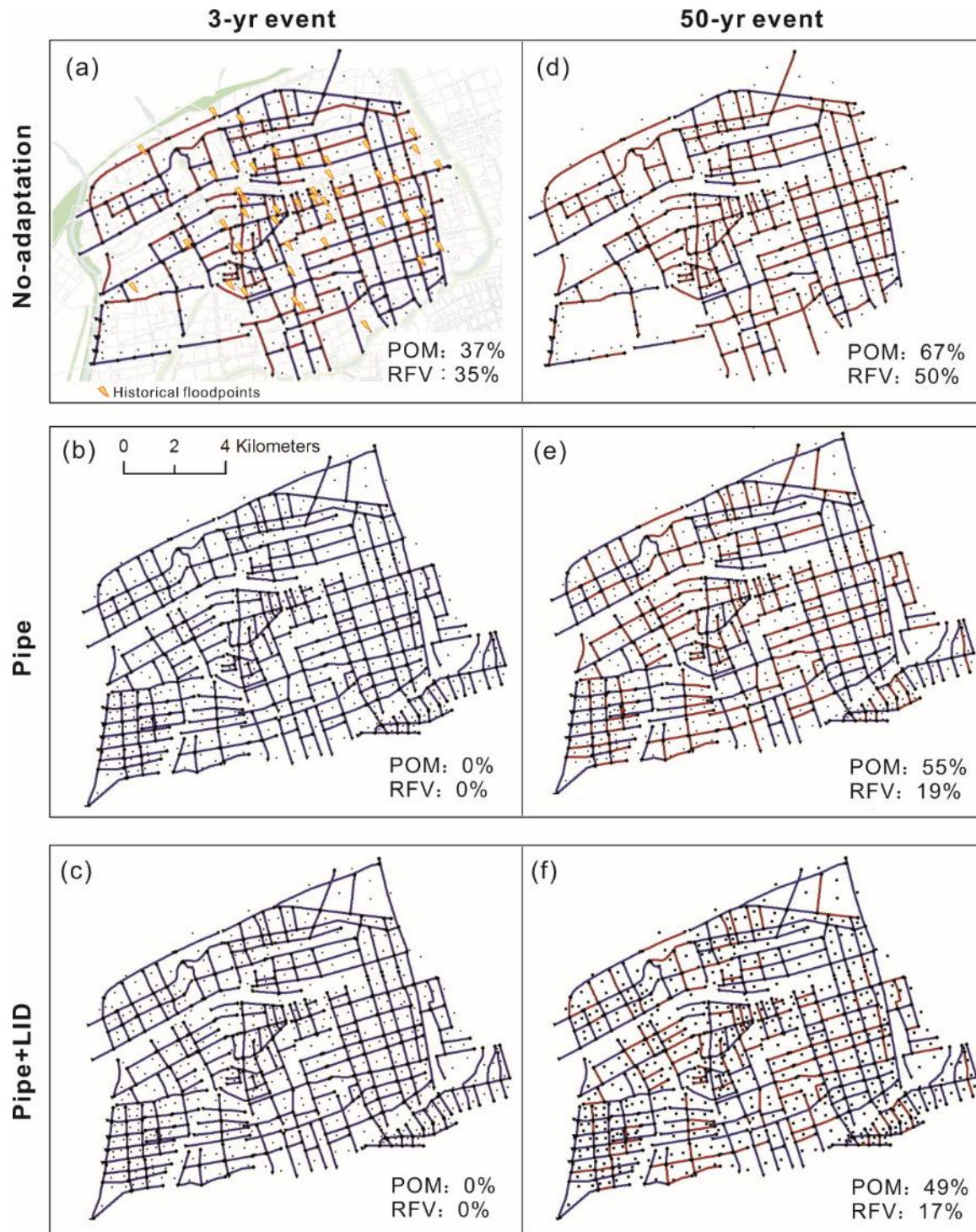
Figure 5 *Spatial distribution of overloaded pipelines (red colour) induced by the current 3-yr (left column) and 50-yr extreme events (right column) without and with adaptations. The total percentage of overloaded manholes (POM) and ratio of flood volume (RFV) are summarized.*

6. Manuscript's title Show the name of the case study and the country. Limit to Adaptation, delete mitigation, delete risk.

Response*: Thanks for the suggestion. In the revision, we deleted the "risk' and added the study region name and country. But we tend to keep "mitigation" in the title as we believe it is important although we emphasize the importance of considering adaptions in assessing climate change impacts on future urban floods. This is because the role of adaptations in reducing flood volume is highlighted through comparing with the reduced floods by climate mitigation. Indeed, comparing the reduction of flood volume by climate mitigations (via reduction of greenhouse gas emissions) and local adaptations (via improvement of the drainage system) indicates that local adaptations are more effective than climate mitigations in reducing future flood volumes.*