Hydrol. Earth Syst. Sci. Discuss., 10, C3587–C3598, 2013
www.hydrol-earth-syst-sci-discuss.net/10/C3587/2013/

Hydrology and Earth System Sciences
Discussions

Interactive comment on "Using the Storm Water Management Model to predict urban headwater stream hydrological response to climate and land cover change" *by* J. Y. Wu et al.

J. Y. Wu et al.

jrrt@iastate.edu

Received and published: 30 July 2013

R1: This paper assesses the combined impacts of climate and land cover changes on urban storm water hydrology in five urban watersheds in the Mid-western US using the SWMM. Building upon previous research, the current research is carefully designed, well-structured, and generally easy to follow. The results of the study would be interesting to a wider hydrologic science community. While the intention of this paper is clear, some methodological issues and assumptions of their modeling need to be stated more explicitly. The literature review and discussion could be strengthened as well to provide a rich context of the current research.

We appreciate these comments from our reviewer and agree that including more explicit information on the methods we used and the assumptions we made will be useful. In addition, we will strengthen the literature review as indicated in the following paragraphs.

R1.1. The uncertainty of the SWMM parameters in future impact assessment can be better addressed. While the streamflow data were collected for about 5 months, only one storm event was used to calibrate the SWMM, and another event was used for validating the SWMM. Since calibration is done manually, it is uncertain how SWMM parameters derived from such a limited event can be robust enough to assess future climate and land cover change impacts. The authors might find the following reference useful for addressing some aspects of uncertainties in their modeling of climate and land cover impacts on urban hydrology. Jung, I.-W., Chang, H. and Moradkhani, H. (2011) Quantifying uncertainty in urban flooding analysis considering hydroclimatic projection and urban development effects, Hydrology and Earth System Sciences 15(2): 617-633.

We agree that we should include a description of the uncertainty associated with the model predictions. We will add the following text describing analysis of uncertainty to the methods, results, and discussion sections as per the following.

Methods (text to be added at p. 7102, l. 12): "2.9 Evaluation of model uncertainty Because we manually calibrated the models, we also analyzed uncertainty associated with three of the model input parameters, by varying sub-catchment width by ±10% (Gironas et al., 2009), and by varying Manning's n to test two plausible end values for pervious surfaces (0.2 and 0.5) and natural channels (0.04 and 0.055) (Chow, 1959). Given that SWMM is run through a GUI, extensive analyses were not practical, so we assessed one watershed (WS 4, which was used in the largest number of scenarios) and tested uncertainty by changing one of these parameters at a time while holding all others constant. We used unit-area peak discharge to measure changes in model results, and R2 and NSE to evaluate model performance as we did for calibration and validation."

Results (text to be added at p. 7105, l. 9; also one new table and one new figure): "3.5 Evaluation of model uncertainty Our analyses indicated that variation (± 10%) in sub-catchment width did not change model performance (as measured by R2 and NSE), and caused very minor changes in unit area peak discharge (a 0.15% decrease with decreased width, and a 0.25% increase with greater width, Table 6, Figure 6). Changes to Manning's n also had little effect: for pervious surfaces there were no changes, and for natural channels when Manning's was set at 0.04, only unit area peak discharge changed, decreasing by 1.22%. When the same parameter was increased to 0.055, model R2 decreased slightly to 0.90, NSE decreased to 0.86, and unit-area peak discharge decreased by 2.63% (Table 6)." Because the submission system dose not allow us to upload tables, we added the table in Supplement as a pdf for now. The table will go into text in final paper.

Table 6 (new). Uncertainty analyses for variations sub-catchment width and Manning's n (impervious surface and natural channels) for WS4. In each test run, only one parameter was changed and others were held constant.

Fig. 6 (new). Hydrographs for uncertainty analyses based on variations in sub-catchment width and Manning's n (impervious surface and natural channels) for WS4.

Discussion (text to be added at p. 7109, l. 25): "4.7 Model uncertainty There is uncertainty associated with predictive hydrological modeling for both single events (e.g. Zhao, Chen, Wang, and Tong, 2013) and across longer time spans (e.g. Jung, Chang, and Moradkhani, 2011). Because we focus on small watersheds and have relatively high-resolution data for their biophysical characteristics, we used the approach of carefully calibrating and validating the models to control for some of this uncertainty, and we used conservative model parameters for our projections that have also been used in previous studies (Chow 1959; Gironás, Roesner, and Davis, 2009; Meierdiercks, Smith, Baeck, and Miller, 2010). Our uncertainty analyses, based on causing varia-

tion in sub-catchment width and Manning's n for both pervious surfaces and natural channels indicated little effect of variation in these parameters on one of our response variables and on model performance as measured by standard statistics. However, we also acknowledge the likely importance of several sources of uncertainty (as per Jung et al., 2011), including that due to natural variability, future precipitation projections, other hydrological parameters within the model, and land cover change projections."

R1.2. The assumption(s) of a future climate change scenario need to be stated more clearly. A future climate change scenario, namely a precipitation change scenario, was created based on the trend of mean annual increase in precipitation in the study area and was applied for one summer rainfall event. What is the rationale of using the 10 June 2011 event as a reference period climate? Is this a typical rainfall event in the study area? What is the recurrence interval of that event? Is it reasonable to assume that a precipitation increase will be uniform throughout the year in the future? Do regional climate downscaling modeling results agree with this assumption?

We will add the following text to clarify our assumptions (on p. 7099, l. 25): "The June 10, 2011 current condition event represents a 1 h, 2-month recurrence interval event in this region. We chose this event because it represents a common precipitation event, would not be likely to induce flooding (which would preclude estimates of response variables that describe flow dynamics within the channel), and was intermediate between the calibration (approximately 11mm) and validation (approximately 22mm) events, reducing some of the uncertainty associated with the hydrological projections. We based our projection on a simple linear regression model, and we do not assume that precipitation increases would necessarily be uniform throughout the year, but we have used the general projection to create a single hypothetical future event. Further, although other methods could be used to generate future precipitation scenarios, the spatio-temporal resolution of even regional climate downscaling models is relatively coarse for application at headwater stream/single event scales."

R1.3. The assumptions of land cover change projection and the method of land distribution over space can be better interpreted. It appears that future land cover change impacts are only addressed through changes in impervious surface areas (ISA). As stated in line 20 of Page 7100, the authors distribute increases in ISA evenly across each watershed. Does this mean that new ISA will be distributed spatially randomly or completely dispersed? What algorithm and computing environment is used to conduct this task? It seems that the authors used a semi-distributed approach (as explained in section 2.7), but I could be wrong.

That is correct – we used the Excel input file to increase impervious surfaces within each sub-catchment. We will add the following text to clarify our approach to simulating land cover change (p. 7100, l. 9): “Our assessment of future land cover change impacts were based solely on predicted changes in impervious surface cover in each of the study watersheds.” and (p.7100, l. 19): “We used a semi-distributed approach to increase percent impervious surface by the projected amount within each sub-catchment of each watershed by adjusting the values for each of them in the input file for each model. We did not change the amount or distribution of storm sewer infrastructure for this analysis.”

R1.4. Additionally, how did the authors assume potential changes in storm sewer pipes network and density as urban development areas expand? Since storm sewer systems directly short-cut rainwater to streams, it is important to consider where they go underground and where they come up land surface.

We did not have access to storm sewer development plans, and assumed the same storm sewer system in spite of projected increases in IS (which we will include in the text as indicated above). We will acknowledge that this is a limitation of our study (p. 7108, l. 1) by adding the following statement: “In addition, the magnitude of stream responses to predicted land cover change in our study may underestimate actual responses given that we did not project changes in the storm sewer conveyance system that would likely move precipitation more quickly to the stream.”

R1.5. Figure 1 can be improved. Instead of showing the whole city area, it is better to focus on the study watershed and show relative distribution of impervious surface areas in each study watershed. As it stands, it is difficult to see where in the study watershed has impervious surface areas. We have revised Figure 1 per this suggestion:

Fig. 1 (revised). Five headwater stream watersheds located in four cities (one each in Altoona, Ankeny, and Johnston, and two in Pleasant Hill) in Polk County, central Iowa. Shaded areas represent impervious surface in 2011, watershed boundaries for WS1 through WS5 are outlined with red lines.

R1.6. The authors need to give proper credit to previous related work. The study of the combined impacts of climate change and land development on hydrology using hydrologic simulation models has at least a decade of history in a global literature. The authors should give due credit to the following references to draw wider international audience.

Chang, H. (2003) Basin Hydrologic Response to Changes in Climate and Land Use: The Conestoga River Basin, Pennsylvania. Physical Geography, 24(3): 222-247.

Chung, E. S., et al. (2011). The relative impacts of climate change and urbanization on the hydrological response of a Korean urban watershed. Hydrological Processes 25(4): 544-560.

Poelmans, L., et al. (2011). The relative impact of climate change and urban expansion on peak flows: a case study in central Belgium. Hydrological Processes 25(18): 2846-2858. The authors also find the following review paper useful for the revision of their paper. Praskievicz, S, and Chang, H. (2009) A review of hydrologic modeling of basin-scale climate change and urban development impacts, Progress in Physical Geography 33(5): 650-671.

We appreciate the suggestion for expanding our review of previous work, and will modify our text in the introduction to include these papers (by citing them on p. 7095, l. 10, and by including these descriptions (to be inserted on p. 7095, beginning l. 12):

"For example, Chang (2003) used two GCMs (the Canadian Centre model and Hadley Centre model) to predict climate change in conjunction with an empirical urban growth scenario to predict land cover change for the 2030s in the Conestoga River basin in Pennsylvania, USA. Predicted hydrological responses, simulated using the AVGWLF model, indicated a 14% decrease in mean annual streamflow using the Canadian Centre model versus an 11% increase using the Hadley Centre model. Predicted streamflow for the whole basin increased by only 0.4% for a 15.5% increase in urban land area. Chung et al. (2011) investigated an integrated approach using a down-scaling model (SDSM) with HSPF and the Impervious Cover Model (ICM) to predict flow and pollutant concentration in the Anyangcheon watershed in Korea under three climate conditions and three land use change scenarios. They concluded that climate change had greater effects in terms of increasing flow rates, and that land cover change had greater effects in terms of increasing stream water pollutant concentration. Poelmans et al. (2011) used statistical downscaling of 58 GCM/RCM runs to predict future climate scenarios and three different urban growth rates to predict outcomes for the 2050s in a small suburban catchment in the Flanders-Brussels region, Belgium. Their lumped hydrological model simulated an 18% decrease in peak discharge under a projected dry scenario and a 30% increase in peak discharge under a wet summer scenario. Land cover change scenarios predicting increases in developed land ranging from 70 to 200% resulted in increases of peak discharge that ranged from 6–16%."

In addition, we will add the following to our introduction and discussion sections: Praskievicz and Chang, 2009 (p. 7100, l. 5; p. 7094/5; p. 7106, l. 22), Chen et al., 2005 (p. 7094/5; p. 7108, l. 20), Davis Todd et al., 2007 (p. 7108, l. 24), and Tang et al., 2005 (p. 7108, l. 20).

R1: Other comments: R1: Page 7096, line 24. Average annual precipitation for what period?

Our previous statement was based on an average for annual precipitation measured from 1895 to 2011. We have revised our estimate which is now based on the period 1987 – 2011 and will modify the text (p. 7096, l. 24) to read: "…with average annual precipitation over the most recent 25 years of 905 mm (National Climatic Data Center, 2012)."

R1: Page 7097, lines 2-5, Table 1 repeats the same information. I suggest the authors delete the two sentences. Simply say something like "Table 1 reports study watersheds characteristics…."

We will modify the text here to read: "Watersheds exhibited variation in size, initial percent IS, and average slope (Table 1)."

R1: Page 7098, line 15, Insert "comma" before "and"

We will do so: "…collect precipitation, and the kinematic…"

R1: Page 7099, lines 15-20. Remove the description of the NSF statistic. It is well-known in the hydrologic science community.

We would prefer to retain this description if possible for readers who may not be familiar with it (e.g. those outside the hydrologic science community).

R1: Page 7101, lines 7-8, Why was WS4 chosen for assessing the effects of different distributions of land cover changes?

We will insert the following rationale for this choice in the text on p.7101, l. 9: "…three sections (Fig. 2). We chose WS4 because it initially had evenly distributed IS and was projected to have a relatively large IS increase. The three sections…"

R1: Page 7106, lines 25-27. Remove "Given variation… five study watershed". This does not well connect to the next sentence.

We will re-write the sentence to read: "In spite of considerable variation in the aforementioned characteristics among the five watersheds we studied (Table 1), consistent changes in the three hydrological indices for these watersheds corresponding to the gradient in % IS suggests that it can be a robust indicator…"

R1: Page 7108, line 16. This is owing to differences in the magnitude of relative changes in different projections.

We will re-write this sentence to include this idea: "…have been inconsistent, possibly owing to differences in prediction methods as well as in the magnitude of relative changes in the projections used to make the predictions."

R1: Page 7109, lines 19-20. "addition of impervious surface areas…. stream hydrology and ecology" Be careful about the interpretation of the simulation results. This is only true if you look at the outlet of the whole watershed, but maybe not necessarily at different points in each sub-watershed (ditto for conclusions point #3).

We will rewrite p. 7109, l. 18-20: "…addition of impervious surface areas in the upstream section of WS4 would have local effects within that portion of the stream, but would likely have less impact on stream hydrology and ecology at a whole-watershed scale." And p. 7111, l. 1-2: "…identifying locations for development that would minimize stream degradation at a whole-watershed scale in small urban watersheds."

References

Chang, H.: Basin hydrologic response to changes in climate and land use: The Conestoga River Basin, Pennsylvania, Phys. Geogr, 24, 222-247, 2003. Chen, J. F., Li X. B., Zhang, M.: Simulating the impacts of climate variation and land-cover changes on basin hydrology: A case study of the Suomo basin, Sci. China Ser. D, 48, 1501-1509, 2005. Choi, W.: Catchment-scale hydrological response to climate-land-use combined scenarios: a case study for the Kishwaukee River Basin, Illinois, Phys. Geogr., 29, 79-99, 2008. Chow, V. T.: Open-Channel Hydraulics, McGraw-Hill Book Co., New York, 1959. Chung, E., Park, K., and Lee, K.: The relative impacts of climate change and urbanization on the hydrological response of a Korean urban watershed. Hydrol.

Process., 25, 544-560, 2011. Davis Todd, C. E., Goss, A. M., Tripathy, D. and Harbor, J. M.: The effects of landscape transformation in a changing climate on local water resources. Phys. Geogr., 28, 21-36, 2007. Gironás, J., Roesner, L. A., and Davis, J.: Storm water management model applications manual. U.S. Environmental Protection Agency, Cincinnati, OH, 2009. Huong, H. T. L., and Pathirana, A.: Urbanization and climate change impacts on future urban flooding in Can Tho city, Vietnam, Hydrol. Earth Syst. Sc., 17, 379-394, 2013. Jung, I. W., Chang, H., and Moradkhani, H.: Quantifying uncertainty in urban flooding analysis considering hydro-climatic projection and urban development effects, Hydrol. Earth Syst. Sc., 15, 617-633, 2011. Meierdiercks, K. L., Smith, J. A., Baeck, M. L., and Miller, A. J.: Analyses of urban drainage network structure and its impact on hydrologic response, J. Am. Water Resour. As., 46, 932-943, 2010. Poelmans, L., Van Rompaey, A., Ntegeka, V., and Willems, P.: The relative impact of climate change and urban expansion on peak flows: a case study in central Belgium, Hydrol. Process., 25, 2846-2858, 2011. Praskievicz, S, and Chang, H.: A review of hydrologic modeling of basin-scale climate change and urban development impacts, Prog. in Phys. Geogr. 33, 650-671, 2009. Tang, Z., Engel, B. A., Pijanowski, B. C. and Lim, K. J.: Forecasting land use change and its environmental impact at a watershed scale. J. Environ. Manage., 76, 35-45, 2005. Zhao, D. Q., Chen, J. N., Wang, H. Z., and Tong, Q. Y.: Application of a sampling based on the combined objectives of parameter identification and uncertainty analysis of an urban rainfall-runoff model, J. Irrig. Drain. E.-ASCE, 139, 66-74, 2013.

Please also note the supplement to this comment:
http://www.hydrol-earth-syst-sci-discuss.net/10/C3587/2013/hessd-10-C3587-2013-supplement.pdf

---

Interactive comment on Hydrol. Earth Syst. Sci. Discuss., 10, 7091, 2013.

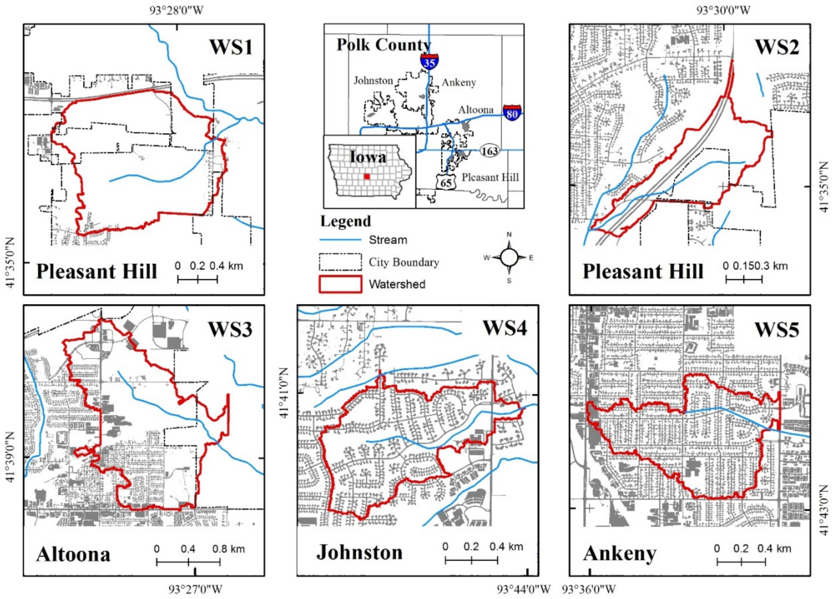
93°28'0"W
WS1
Pleasant Hill
0 0.2 0.4 km
41°35'0"N
Polk County
Johnston
Ankeny
Altoona
Pleasant Hill
Iowa
35
80
163
65
Legend
Stream
City Boundary
Watershed
N
W
E
S
93°30'0"W
WS2
Pleasant Hill
0 0.15 0.3 km
41°35'0"N
WS3
Altoona
0 0.4 0.8 km
41°39'0"N
93°27'0"W
WS4
Johnston
0 0.2 0.4 km
41°41'0"N
93°44'0"W
WS5
Ankeny
0 0.2 0.4 km
41°43'0"N
93°36'0"W

Fig. 1.

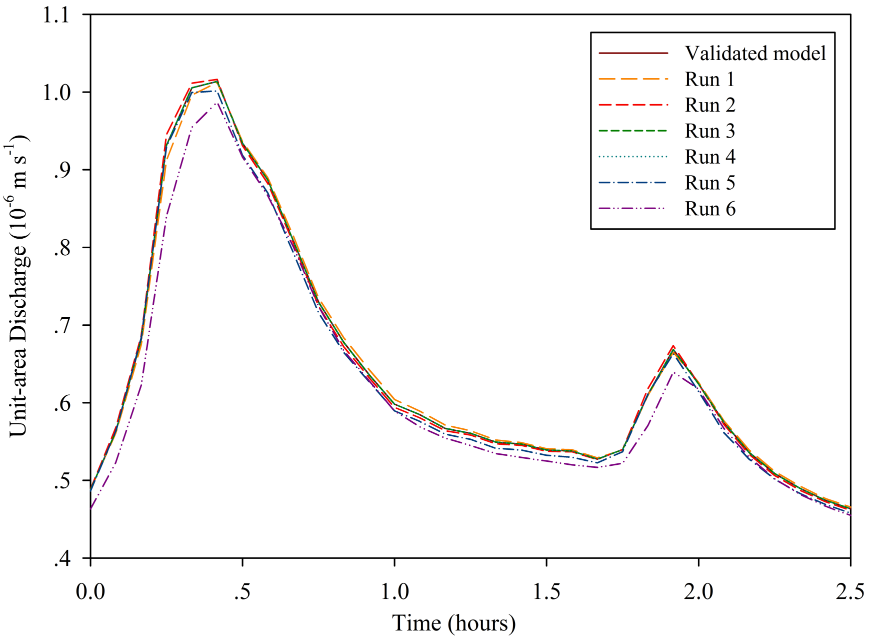
1.1
1.0
.9
.8
.7
.6
.5
.4
Unit-area Discharge (10^-6 m s^-1)
0.0
.5
1.0
1.5
2.0
2.5
Time (hours)
Validated model
Run 1
Run 2
Run 3
Run 4
Run 5
Run 6

Fig. 2.