

Interactive comment on “Assessing the hydrologic restoration of an urbanized area via integrated distributed hydrological model” by D. H. Trinh and T. F. M. Chui

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We would like to thank Dr. Barron for her helpful comments, especially about the influences of soil properties, rainfall data interval and simulation time steps on rainfall partitioning and river discharge. We have carried out a sensitivity analysis on the above three factors. The results, reassuringly, lead to the same main conclusions that were drawn previously. Please see the detailed responses below.

1. Models do not allow developer to influence recharge, runoff coefficients, etc, but only the catchment and subsurface characteristics, the conceptualisation of the catchment

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water balance has to be well defined, particularly when those characteristics have to be spatially distributed.

[Response]

We apologize for not stating it clearly in the original manuscript. In terms of rainfall partitioning between direct runoff, infiltration and groundwater recharge, we cannot explicitly specify the proportions as the model simulates the infiltration and subsurface water movement according to the different soil properties and rainfall conditions. However, in terms of direct runoff from paved vs unpaved areas, we can specify a “paved runoff coefficient” that defines the fraction of ponded water that drains to the drainage system. Thus, if 25% of surface area is paved, then a paved runoff coefficient of 0.25 removes 25% of the ponded water and drains it directly to the river network. The remaining 75% will be available for infiltration and those that does not infiltrate will flow as overland flow to the adjacent cells. For our case study, the paved runoff coefficient is respectively set as 0.3 and 0.7 for pervious and impervious surfaces, as specified in the manuscript.

We will make it clearer in the revised manuscript.

2. The main concern about the reviewed paper is related to an absolute lack of any observation data (apart from meteorological data), and all presented results and discussion are solely based on the model outcome. This is the main limitation of the suggested results: the model doesn't seem to be validated at all. In couple models, rainfall partitioning to recharge and runoff is depended on the soil properties, and it is very sensitive to unsaturated zone parameters. Incorrect partitioning, resulting from inadequate parameters selection propagates the error to simulated river flow. How much trust one can put in the model outcomes, when no evidences were offered on whether the model treats the rainfall partitioning correctly? Even in relative terms, the analysis of difference between selected scenarios on baseflow or peak flow could be wrong.

[Response]

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We understand and acknowledge that our models, without calibration and validation, are not producing the exact and precise responses of any particular system. Instead, we are hoping to develop general understandings on the overall effects of green structures using the physically based models with realistic choice of parameters, and that the generic results and insights are more widely applicable, as we have stated on p. 4105 lines 19-26 and on p. 4118 lines 1 to 5. We also agree with Dr. Barron that rainfall partitioning to recharge and runoff is sensitive to soil properties. We therefore simulate the different scenarios with a soil hydraulic conductivity that is one order of magnitude lower. For the aggregated water balance over one year (Fig.1), the rainfall partitioning still follows the same patterns as the original simulation. For example, when compared with the pre-urbanized scenario, there is still close to a 10% increase of direct runoff and 10% decrease in evapotranspiration in the urbanized and hybrid scenarios. There is also more baseflow in the hybrid scenario when compared to the urbanized one due to the green structures. In terms of peak outlet discharge (Fig.2), the low hydraulic conductivity leads to an increase of peak discharge by 50 m³/s in the pre-urbanized scenario. Similarly, the decrease in hydraulic conductivity also results in a higher peak discharge in the hybrid scenario. However, the amount of increase, 100 m³/s, is higher than pre-urbanized one. This is because the low hydraulic conductivity of the native soil not only reduces rainfall infiltration but also limit the exfiltration of the bio-retention system. The change in hydraulic conductivity however does not significantly affect the peaks in the urbanized scenario due to the low percentage of pervious area. Although the absolute values of peak discharges change with the hydraulic conductivity, the relative differences among the scenarios are still the same. In other words, there is still a drastic increase of peak discharge in the urbanized scenario and a partial recovery in the hybrid one. In conclusion, although the change in hydraulic conductivity leads to some changes in the model results in terms of the aggregated water balance as well as the absolute values of outlet peak discharge; the main observations of how urbanization influences hydrological conditions and how green structures restores it are still the same. Thus, we believe that the model outcomes are reliable for drawing the main

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conclusions of this study.

3. About the simulation time step and rainfall input resolution: If the input data was hourly rainfall, how these data were used for when the river routing was model with time step of 1 min, while other components of the water balance – 0.25 and 0.5 hours?

[Response]

When the time steps taken are finer than the data input, the model would then linearly interpolate the data for the simulated time step. The simulation time steps of the several components can be different given that they meet their individual model requirement. Also, to simulate the flow exchanges between the components, their time steps have to be even multiples of each other (e.g., overland flow time step is even multiple of river routing one; saturated zone is even multiple of unsaturated zone). This study examines the rapid response of peak outlet discharge (in time scales of minutes), as well as the long-term groundwater response (in time scales of days and months). Thus, we believe that our original choices of data resolution and simulation time steps (i.e., 1 min for river routing, 0.25 hours for overland flow, 0.5 hours for unsaturated zone and 12 hours for saturated zone) are good compromises. It should also be noted that other than river routing, the time steps specified are maximum allowed ones. During periods of heavy rainfall, the actual time steps are reduced to maintain model stability as well as accuracy. We will provide more information about rainfall input interval and choice of time step in the revised manuscript.

4. About sensitivity analysis: Was any sensitivity analysis applied to assess 1 hourly rainfall data distribution with that hour on the simulated river flow and particularly the peak flow analysis?

[Response]

We thank Dr. Barron very much for the suggestion. We have carried out a sensitivity analysis with two additional simulations:

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1) Original rainfall data interval (1 hour) but coarser simulation time steps (5 min for river routing, 0.5 hours for overland flow, 1 hour for unsaturated flow, and 12 hours on groundwater flow)

2) Rainfall data of smaller interval (5 min) with the original simulation steps The peak outlet discharges (i.e., highest peak, medium peak and small peak) of the above two simulations are presented in Fig. 3 together with those from the original simulation. The increase in simulation step sizes does not affect the time and the magnitude of the peak discharges. The more detailed rainfall input increases the peak discharges at most 20 m³/s, and changes the time of occurrence by at most 1 hour. However, the changes are not significant enough to affect the main conclusions of this study. Thus, we think the original rainfall data interval and the simulation step sizes are reasonable for this study. We are happy to add the above findings to the revised manuscript.

5. About vertical model discretisation: What was the reason for vertical model discretisation for 45 layers? It is not particularly clear why such discretisation required.

[Response]

The vertical discretisation is chosen to match with the soil profile description and the required resolution of the simulation. The information on the soil profile in the studied catchment is relatively detailed in the top layer. In addition, the Richards equation is used to accurately simulate the infiltration process in the unsaturated zone. The vertical discretisation should ideally vary from 10-25 cm in the uppermost grid points to 50-100 cm in the bottom of the top soil profile. Therefore, we apply a vertical discretization of 20 cm for the first 1 m depth, 50 cm for the following 5 m depth, and then 100 cm for the rest of the domain. This discretisation results in 45 vertical layers.

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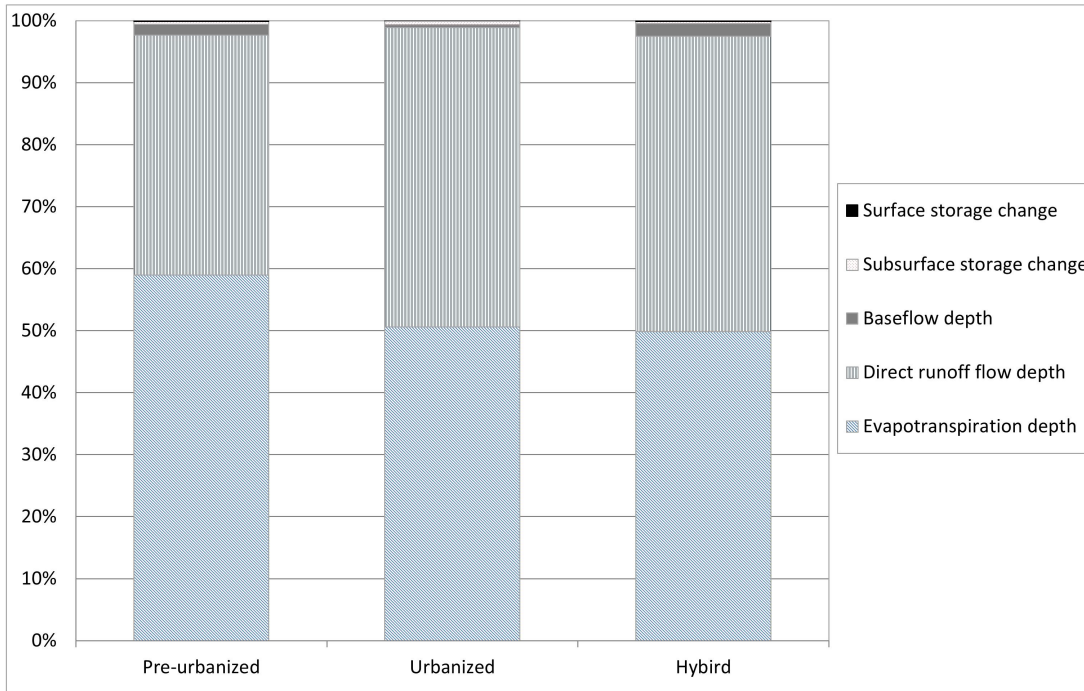


Fig. 1. Water balance aggregated over one year for different scenarios with a lower soil hydraulic conductivity

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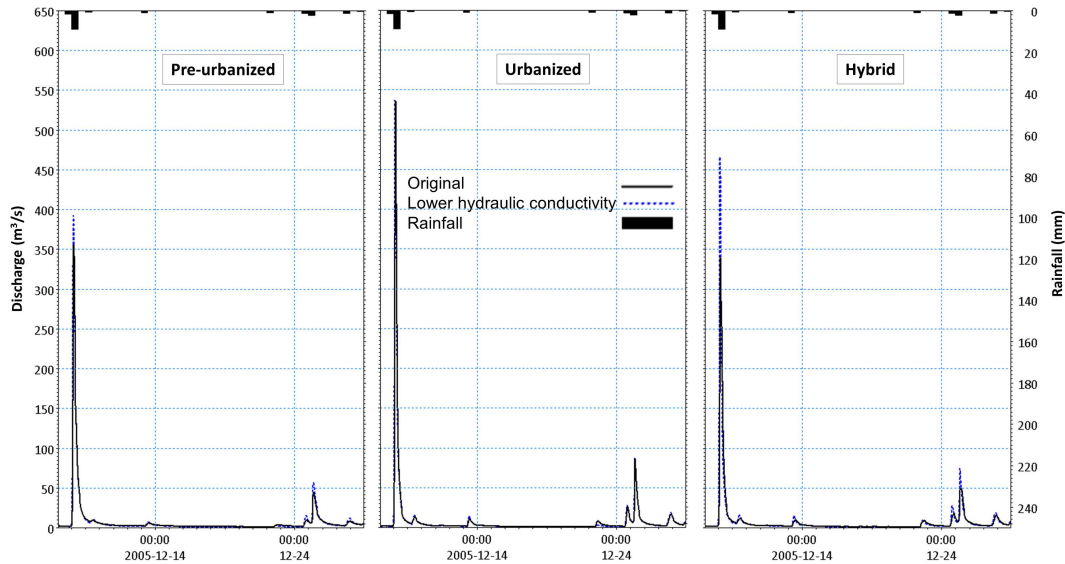


Fig. 2. Comparison of peak discharges under different scenarios

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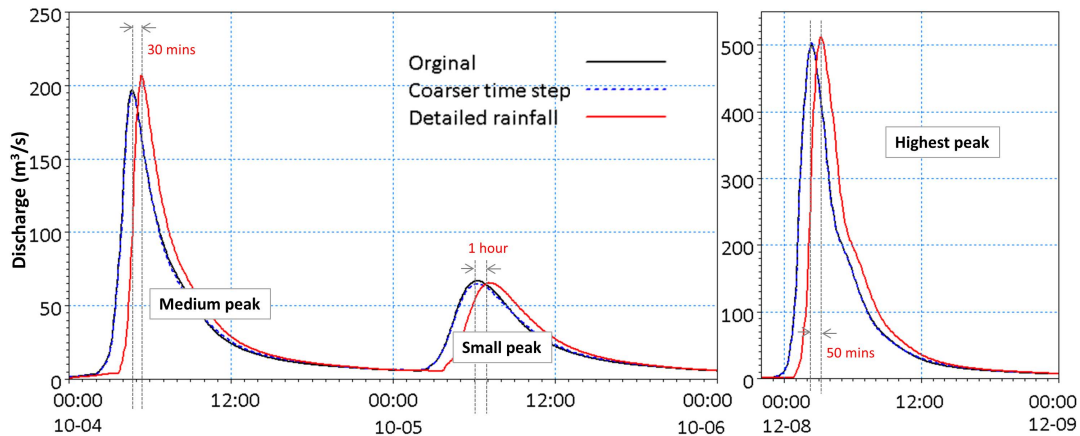


Fig. 3. The influences of time step and rainfall data resolution on peak outlet discharges in Bio-retention scenario

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