Reply to comments of Anonymous Referee #2

We thank anonymous Referee #2 for reviewing our manuscript. The authors are grateful for the insightful comments which provide great suggestions to improve the manuscript.

Comment: Line 26: “Experimental catchments” What this means? It is not clear what you are trying to say. Rephrase the sentences.

Reply: We agree with the referee that the term “Experimental catchments” needs further explanation in the manuscript. We will rephrase the following sentences:

Lines 24-28: “Water resource problems, including the effects of urban development, alternative management decisions, and future climate oscillation on streamflow and water quality, require a deep understanding and accurate modeling of earth surface processes at the catchment scale to be addressed (Gassman et al., 2014). In order to understand catchment processes, it is necessary to obtain detailed weather data and catchment observations related to runoff, water stage, erosion, soil moisture, and water quality. Experimental catchments are properly designed and well-monitored catchments that aim to provide databases of long-term historical hydrological data, which help analyze the mechanisms governing surface runoff (Goodrich et al., 2020).

Comment: Line 28: They are? Who are they? There is two times the sentence starting with “they” but it is not clear who or what they are.

Reply: We agree with the referee that the sentence needs clarification. The word “they” refers to the term experimental catchments. We will merge the first two paragraphs and we will make the following changes in the manuscript:

Lines 24-45: “Water resource problems, including the effects of urban development, alternative management decisions, and future climate oscillation on streamflow and water quality, require a deep understanding and accurate modeling of earth surface processes at the catchment scale to be addressed (Gassman et al., 2014). In order to understand catchment processes, it is necessary to obtain detailed weather data and catchment observations related to runoff, water stage, erosion, soil moisture, and water quality. Experimental catchments are properly designed and well-monitored catchments that aim to provide databases of long-term historical hydrological data, which help analyze the mechanisms governing surface runoff (Goodrich et al., 2020). In addition, experimental catchments contribute in the development and validation of numerous watershed models and can be used as validation sites for satellite sensors (Tauro et al., 2018). Furthermore, experimental catchments can monitor groundwater and river water quality with the use of tracer experiments which can estimate the residence and travel times of water in different components of the hydrological cycle (Hrachowitz et al., 2016; Stockinger et al., 2016). Bogena et al. 2018 presented an extensive overview of hydrological observatories that are presently operated worldwide with various environmental conditions. Among those, the US Department of Agriculture-Agricultural Research Service’s (ARS) Experimental Watershed Network has operated over 600 watersheds in its history and currently operates more than 120 experimental hydrological watersheds (Goodrich et al., 2020)”.

Comment: Line 47-49: Which are these models? Why did you choose SWAT?

Reply: The referee is right to point out this issue. Hydrological models can be categorized as (i) point-scale models, (ii) field-scale models, and (iii) watershed-scale models (Arnold et al., 2015; Moriasi et al., 2007). Point-scale models (i.e., SHAW, COUPMODEL, SWIM3, MACRO, and HYDRUS) are usually used to simulate the physical or chemical processes that occur at a soil profile. Field-scale models (i.e., DRAINMOD, ADAPT, EPIC, DAISY, and, RZWQM2) represent the basic processes of hydrology, soil erosion, vegetation, sediment transport, and pesticides occurring in the combined soil-water-plant system. Watershed-scale models (i.e., SWAT, APEX, HSPF, WAM, KINEROS and, MIKE-SHE) incorporate processes of more spatial and temporal complexity and divide basins into sub-basins, response units or cells.

Among those watershed-scale models, the SWAT model (Arnold et al., 2012) was used in this study. The SWAT model is an open-source software, and it is supported by online documentation and a literature database (Gassman et al., 2014, 2007; Tan et al., 2020). The application of the model involves the division of the hydrological basin into sub-basins and then into Hydrological Response Units (HRU) (Neitsch et al., 2011). In this way, different values of rainfall, temperature, and evapotranspiration, different crops, and different soil types can be simulated. Furthermore, SWAT can be linked with QGIS, which is a free and open-source platform. QSWAT (Dile et al., 2016), which was used in this study, prepares the inputs easily for SWAT, has a friendly user interface, and has the ability to visualize the results, which can be helpful for the interpretation of the many SWAT outputs. The study area is characterized as a mixed-land-use area with high complexity and spatial distribution of input data. The use of a semi-distributed model, such as SWAT, is considered the most appropriate choice because SWAT enables the simulation of as wide a range of processes as possible. Therefore, SWAT was considered a credible tool for discharge simulation for this study area.

We referred to watershed-scale models specifically. We will rewrite the paragraph as follows:

Lines 46-52: "Hydrological and water quality models have been widely used to assess water resource problems and to investigate hydrological processes, land use and climate change impacts and best management practices (Daggupati et al., 2015). In recent decades, various watershed-scale models (i.e., SWAT, APEX, HSPF, WAM, KINEROS and, MIKE-SHE) have been developed to operate with different levels of input data and model structure complexity (Arnold et al., 2015; Moriasi et al., 2007). Among the above watershed-scale models, the SWAT program (Soil and Water Assessment Tool) (Arnold et al., 2012) was selected for this study. SWAT is a physically based, semi-distributed, continuous time river basin model and has five main official versions, SWAT2000, SWAT2005, SWAT2009, SWAT2012, and SWAT+. It was selected because is an open source code, has a wide range of online documentation and literature database and has been applied to catchments of various sizes and to several temporal scales (e.g., monthly, daily and sub-daily time step) (Gassman et al., 2014, 2007; Tan et al., 2020). Furthermore, it can be linked to QGIS, an also free and open-source platform, and has the ability to visualize the results, which can be helpful for the interpretation of the many SWAT outputs (Dile et al., 2016)".

Comment: Line 72: Are you used SWAT+?

Reply: We thank the referee for the correction. We used SWAT 2012 (rev 681) in the QSWAT interface. We will rewrite the sentence in the revised manuscript to be as follows:

Line 72: "In this study, the SWAT 2012 model (rev 681) in the QSWAT interface was used to simulate streamflow in an experimental basin using daily and sub-daily (hourly) rainfall observations".

Comment: Line 72: The aim and innovation of the work need to be better discussed both in introduction and discussion. There is plenty of work which evaluates model performances with different data resolution (soil, morphology and climate. Here some examples which can be useful in discuss the main innovation: How you work give new insight in the research? I cannot see any novelty or secondary elaboration from the canonical SWAT application such as a susceptibility map or future prediction. I suggest to the authors to focus more on this points.

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https://doi.org/10.1016/j.jenvman.2020.110625

https://doi.org/10.5194/hessd-7-4411-2010

Reply: We agree with the referee that the aims and novelty of this study should be more emphasized. This study aims to investigate the complex hydrological processes that take place within a catchment of highly-variable land-use characteristics and the impact of the above on the generation of surface runoff. More specifically the catchment land use/land cover type starts from (i) being almost exclusively rural within its most upstream part, (ii) to peri-urban land use/land cover type within its intermediate part and finally (iii) to urban within its most downstream part. We will re-organize Section 3.2 and Section 3.3 appropriately while in addition to that, we will analyze and discuss the physical meaning of the results in the revised manuscript. We will also provide further description of the objectives and the contribution of this study in the Abstract, Introduction, Results and Discussion sections. In addition, we will explain the peak flow underestimation and we will discuss the disadvantages of the GAML method. We will also aggregate the hourly results to a daily time step in order to compare the performances in the revised manuscript.

We will make the following changes in the Abstract section in the revised manuscript:

Lines 11-22: "SWAT (Soil and Water Assessment Tool) is a continuous time, semi-distributed river basin model that has been widely used to evaluate the effects of alternative management decisions on water resources. This study examines the application of SWAT model for streamflow simulation in an experimental basin with mixed-land-use characteristics (i.e., urban/peri-urban) using daily and hourly rainfall observations. The main objective of the present study was to investigate the influence of rainfall resolution on model performance in order to analyze the mechanisms governing surface runoff at the catchment scale. The model was calibrated for 2018 and validated for 2019 using the SUFI-2 algorithm in the SWAT-CUP program. Daily surface runoff was estimated using the Curve Number method and hourly surface runoff was estimated using the Green and Ampt Mein Larson method. A sensitivity analysis conducted in this study showed that the parameters related to groundwater flow were more sensitive for daily time intervals and channel routing parameters were more influential for hourly time intervals. Model performance statistics and graphical techniques indicated that the daily model performed better than the sub-daily model (daily model: NSE = 0.86, R^2 = 0.87, PBIAS = 4.2%, sub-daily model: NSE = 0.6, R^2 = 0.63, PBIAS = 11.7%). The Curve Number method produced higher discharge peaks than the Green and Ampt Mein Larson method and estimated better the observed values. Overall, the general agreement between observations and simulations in both models suggests that the SWAT model appears to be a reliable tool to predict discharge in a mixed-land-use basin with high complexity and spatial distribution of input data".

We will make the following changes in the Introduction section in the revised manuscript in order to emphasize the objectives of the study:

Lines 72-73: "In this study, the SWAT 2012 model (rev 681) in the QSWAT interface was used to simulate streamflow in an experimental basin using daily and sub-daily (hourly) rainfall observations. The main objectives were to (i) calibrate and validate the SWAT model using streamflow data, (ii) examine which parameters are more sensitive in different time steps, (iii) estimate the influence of rainfall resolution on model performance, (iv) compare the Curve Number method and Green and Ampt Mein Larson method for runoff simulation, (v) examine the accuracy of the sub-daily model and compare the peak discharges and time of peak of the two models in selected rainfall events, and (vi) investigate the suitability of the SWAT model for hourly simulation in a mixed-land-use basin (i.e., blended combinations of land use). Hence, this study will provide essential hydrological knowledge and contribute to the understanding of the earth surface processes of an urban/peri-urban hydrological system with complex land use in order to analyze the mechanisms governing surface runoff at the catchment scale".

We will make the following changes in the Results and Discussion section in the revised manuscript:

Lines 336-340: "In this study, the daily model produced higher discharge peaks than the hourly model and generally estimated better the observed values. These results could be due to drawbacks of the GAML method, such as the requirement for detailed soil information and high resolution rainfall data in a sub-daily time step (King et al., 1999). The GAML method assumes that the soil profile is characterized by homogeneity and that the previous soil moisture is distributed uniformly in the soil profile (Jeong et al., 2010). Therefore, the uncertainty in the resolution of the rainfall data, the heterogeneity of the soil formations and the upcoming difficulty in determining the parameters' values for parameterization could affect the method's efficiency. The selection of sub-daily precipitation input time step as well as the resolution of the precipitation data have a great impact on model results when using the GAML method and it should be based on the scale and characteristics of the watershed (Bauwe et al., 2016; Jeong et al., 2010; Kannan et al., 2007). Furthermore, observational errors in the model input data (i.e., weather, soil and land use data) include inaccuracies in the estimation of channel and hillslope velocities and channel geometry, in the nature of the sensor, environmental conditions and data collection (Guzman et al., 2015). These errors can generate variability, lead to undesired trends, and influence the model calibration and validation results (Kamali et al., 2017). In addition, the complex land use characteristics and processes of an urban/peri-urban environment and assumptions made during the model structure/parameterization process (e.g., selection of parameters for calibration, objective function, and conceptual simplifications) increase the uncertainty of the results."

We will also change the Conclusion section to be as follows:

Lines 347-369: "Experimental catchments provide long term time series of hydrological data which are essential for improved application of best management practices and the development and validation of watershed models. In this study, discharge was monitored for three years (2017-2019) in an experimental basin with mixed-land-use characteristics (i.e., urban/peri-urban), located in Athens, Greece. Discharge simulation, calibration and validation were achieved with the application of SWAT model, which has been increasingly used to support decisions on various environmental issues and policy directions. Daily and hourly rainfall observations were used as inputs to investigate the influence of rainfall resolution on model performance in order to analyze the mechanisms governing surface runoff at the catchment scale. Surface runoff was estimated using the CN method for the daily model and the GAML method for the hourly model.

A sensitivity analysis conducted in this study showed that the parameters related to groundwater flow were more sensitive for daily time intervals and channel routing parameters were more influential for hourly time intervals. These findings indicate that the model operational time step affect parameters' sensitivity to the model output, thus demonstrating the need for different model strategy for the simulation of sub-daily hydrological processes.

Quantitative statistics of the observed and the simulated records indicate that the calibration and validation processes produced acceptable results for both infiltration methods. Additionally, graphical techniques at the outlet station show that both models succeed in capturing majority of seasonality and peak discharge. Generally, the daily model performed better than the sub-daily model in simulating runoff. The CN method produced higher discharge peaks than the GAML method and estimated better the observed values. The differences in the calibrated values of the two models lay mostly in the different runoff estimation methods used by the two models. In addition, errors in the quality of input data, the complex land use characteristics of an urban/peri-urban environment and assumptions made during the model structure/calibration process may increase the uncertainty of the outputs.

Overall, the general agreement between observations and simulations in both models suggests that the SWAT model appears to be a reliable tool to predict discharge in a mixed-land-use basin with high complexity and spatial distribution of input data. Furthermore, this study contributed to the understanding of the mechanisms controlling surface runoff and the parameters than influence the hydrological processes that take place in an urban/peri-urban hydrological environment. It should be noted that several factors such as data limitation, observational errors in input data, complexities of spatial and temporal scales, and inaccuracies in model structure may lead to uncertainty in model outputs. In the future, emphasis will be placed in the quantification of the parameter uncertainty by including more observed variables in the calibration process such as evapotranspiration and soil moisture satellite data."

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