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Reply on RC2

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Author comment on "Deep Learning Methods for Flood Mapping: A Review of Existing Applications and Future Research Directions" by Roberto Bentivoglio et al., Hydrol. Earth Syst. Sci. Discuss., https://doi.org/10.5194/hess-2021-614-AC2, 2022

Reply to anonymous Reviewer #2

We thank the Reviewer for reading our paper and providing detailed and insightful comments. Here we provide answers to the issues raised along with details on the amendments to the original manuscript to be featured in the revision. Unless otherwise specified, reported line numbers refer to the updated version.

Major concern:

1) I suggest the authors provide the time extent of these reviewed publications. Because studies related to deep learning in flood mapping are constantly updated.

The time extent considered for the reviewed publications has now been explicitly mentioned in section 3.1: lines 255-256 "The 3,338 publications obtained were then filtered to include only journal papers *from January 2010 until December 2021*, in the areas of engineering, environmental science, and earth and planetary sciences"

2) It is better to introduce the three flood maps as follows: first to show flood extent or inundation maps, then to illustrate flood susceptibility map, and finally present flood hazard map. Because flood extent or inundation map can be viewed as preliminary work in mapping research. Then, the results of the flood extent maps can be used as training data to predict flood susceptibility. Finally, the flood susceptibility indicates the potential location of future floods. And flood hazard map can be viewed as an extension of a flood susceptibility map that not only considers the location of the flood but also integrate the depth and water extent.

Thank you for this insightful recommendation. We agree with it and we changed the order of the presented flood maps in Section 2.1.2 and Section 3. Moreover, we modified lines 107-112 as follows: "Flood inundation maps determine the extent of a flood, during or after it has occurred (see Fig. 1a). Flood inundation maps represent flooded and nonflooded areas. This application is used for post-flood evacuation and protection planning, and for damage assessment. *These maps can then be used also as observed and calibration data for other applications*. Flood images are obtained through remote-sensing techniques and processed by histogram-based models (e.g., Martinis et al., 2009; Manjusree et al., 2012), threshold models (e.g., Cian et al., 2018), and machine learning models (e.g., Hesset al., 1995; Ireland et al., 2015)."

3) A deep brief network is also an important part of deep learning, which has been used in the flood mapping field. Some studies are shown below:

[1] Shahabi, Himan, et al. "Flash flood susceptibility mapping using a novel deep learning model based on deep belief network, back propagation and genetic algorithm." Geoscience Frontiers 12.3 (2021): 101100.

[2] Shirzadi, Ataollah, et al. "A novel ensemble learning based on Bayesian Belief Network coupled with an extreme learning machine for flash flood susceptibility mapping." Engineering Applications of Artificial Intelligence 96 (2020): 103971.

[3] Pham, Binh Thai, et al. "Can deep learning algorithms outperform benchmark machine learning algorithms in flood susceptibility modeling?." Journal of Hydrology 592 (2021): 125615

We thank the Reviewer for pointing out the applications of Deep Belief Networks (DBN) for flood mapping. Since DBNs are unsupervised methods, we did not include them among the reviewed papers as our manuscript focuses on supervised methods (lines 164-165 in the original manuscript). Nonetheless, we included some of the suggested papers in lines 473-475: "Some works showed that deep belief networks (DBN), an unsupervised variation of MLPs, could outperform standard MLPs in flood susceptibility mapping (e.g., Shirzadi et al., 2020; Pham et al., 2021)."

4) The application perspectives on different mapping scenarios are different. Therefore, the authors should provide specific limitations and future research directions on different mapping frameworks. For example, the deep learning methods for mapping susceptibility focus on predicting the location of potential flood areas by considering the historical location and environmental variables. Therefore, it is important to design an appropriate network to integrate heterogeneous environmental information. For flood extent mapping, it aims to find the continuous inundated areas based on satellite images or UAV images. Some deep learning methods such as semantic segmentation are more appropriate in flood extent mapping.

We thank the reviewer for the useful feedback. We carefully considered the competent suggestions made by the Reviewer concerning the presentation of specific limitations and research directions for the different types of flood mapping applications. We included limitations of each presented flood map in lines 558-563: "Nonetheless, each of the presented maps has its own limitations. Susceptibility maps provide only qualitative results and rely on recorded flood events. Therefore, limited recorded data may lead to incorrect predictions. Moreover, it is important to design an appropriate model to integrate heterogeneous environmental information. Inundation maps mostly consider real events, thus they suffer from the acquisition method's problems. For example, satellites struggle to extract information below clouded areas (e.g., Meraneret al., 2020). Hazard maps, instead, are limited by the accuracy of the underlying numerical simulator."

As regards to flood extent or inundation mapping, most of the presented papers indeed consider semantic segmentation, in the paper referred to as "image segmentation". We added a description of what image segmentation refers to in lines 220-222: "Instead, if the task is to perform image segmentation, i.e., *classify specific parts of an image*, the final layers are composed of de-convolutional layers which perform an operation opposite of convolutional layers, in an encoder-decoder structure".

Minor concern:

1) Figure 1: the legend is overlapped in the main figure.

We removed the legend overlap in Fig. 1.

2) It is better to entitle Section 2.2 as "Deep learning method". Section 2.2.1, 2.2.2, 2.2.3 should be entitled "Multi-layer perceptron", "Convolutional neural network", and "Recurrent neural network", respectively.

We renamed the sections as suggested by the Reviewer.

3) Section 2.2, part 155: lack of related reference in the first sentence.

We added a reference to line 155 of the original manuscript (LeCun et al., 2015).

4) Figure 1: please provide the location information in the caption.

We omitted the location since the purpose of Figure 1 is merely exemplificative; it should not be taken as a necessarily correct estimate of flood inundation, susceptibility, and hazard for the selected area.

5) 5 (a) should be improved.

Figure 5(a) was improved so that the legend does not overlap with the bar plot anymore.

6) Section 5.3 belongs to the future direction, but data scarcity is a kind of limitation. Data enhancement may be a suitable title for this section.

Thanks for the suggestion. Based on the comment and on the common nomenclature used in machine learning, we changed section 5.3 to "Data augmentation".

References:

LeCun, Y., Bengio, Y., and Hinton, G.: Deep learning, nature, 521, 436–444, 2015