Sensitivity of the Flood Risk Maps to the Different Digital Elevation Model's Resolutions

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Introduction

Floods are one of the most widespread and destructive natural disasters. The floods are responsible for claiming more lives and causing more property damage than any other natural phenomena (Chakraborty and Biswas, 2019). Specifically, in Bosnia and Herzegovina , the total economic impact of the disaster (destruction or severe damage to property, infrastructure and goods as well the effects of destruction on livelihoods, incomes and production, among other factors) is estimated to have reached 2.04 billion EUR during the floods of May 2014 (UNDP, 2014). In such situation the importance of an accurate Flood risk maps is evident in order to prevent and/or decreasing the flood damages by quickly evacuating local residents in a safe and proper manner in the event of floods or to facilitate to the planners to identify the prone areas and prioritize their mitigation or response efforts. It is important to the flood experts to use the most adequate tools providing the most precise flood risk maps, following the Flood Directives (2007/60/EC).

In this study, a sensitivity analyses was made to quantify the impact of different DEM resolutions on the flood inundation modelling and as well as on the flood risk maps aiming to provide the best-case scenario of flood risk results using the available DEM (Copernicus

Materials and Methods

Two study reaches in Bosnia and Herzegovina, are chosen for this work paper to represent varying reach length and different riverbed width.

Bregava river, 33.5 km, located in the Adriatic River basin district, starting from the Entity line FBiH/RS to the confluence with the Neretva River.

Joševica river, 7 km, located in Sava River basin district, starting from Lipnica Donja in the municipality of Lukavac to the confluence with the Jala River.

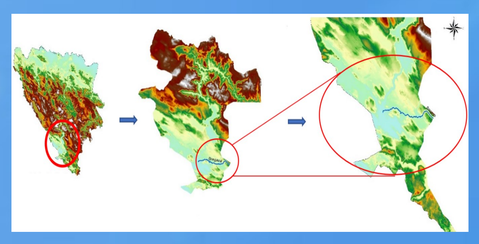

Figure 1. Bregava river section

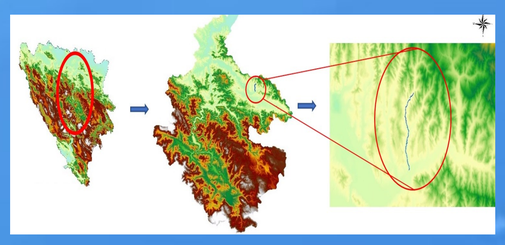

Figure 2. Joševica river section

The method used in this study is based on the HEC-RAS software (the Hydrologic Engineering Centers River Analysis System), creating eight 1D models, four for each study area. The same input data were considered. Four different DEM resolutions were introduced respectively to the models; LiDAR 1x1m which is the most accurate DEM dataset and it is considered as the flood model reference in this study, DEM 5x5m, DEM 20x20m and the open source EU-DEM dataset Copernicus 25x25m. Thus, the DEM will be considered as the unique variable in these models.

A determination of the error index using the Rout Mean Square Error (RMSE) will provide a significant comparison between the different DEM-resolution used in the models.

As a third step in this methodology, the determination of the flood Risk maps for these eight models. The flood hazard maps are based on the results of the hydraulic models. Once these maps are created, their analysis will be carried on to determine the sensitivity of the flood risk to the different DEM-resolution.

Conclusions

This study shows clearly that the use of a low-DEM resolution, overestimates the inundation boundaries and the flood damages. The comparison of the RMSE shows that the error index increases by decreasing the DEM-resolution, but it shows as well a minor percentage between the results of the preliminary Flood Risk Assessment and the EU DEM. So, the coarser DEM can be used in assessment studies. Further researches and investigations are recommended where the flood risk modeling for a small-scale area should include in the methodology the DEM error index in case of the use of a coarser DEM-resolution also it would be useful to work on the water surface elevation error index in terms of vertical errors.

Results and Discussion

Inundation boundaries

The eight hydraulic models were run based on inputs described below and for four different DEM-resolutions 1x1m and 5x5m, 20x20m and 25x 25m, providing the following inundation boundaries, shown in Figure 3.

The Bregava river section's model contains 694 cross sections and 11 bridges. The upstream flood discharges for the return period 1/100 were estimated by 63 m^3/s while the downstream boundary condition was added as a normal depth.

The Joševica river section's model contains 162 cross sections and 21 bridges. The flood discharges for the return period 1/100 were estimated in the upstream river section by 28 m^3/s while downstream was estimated as 55 m^3/s.

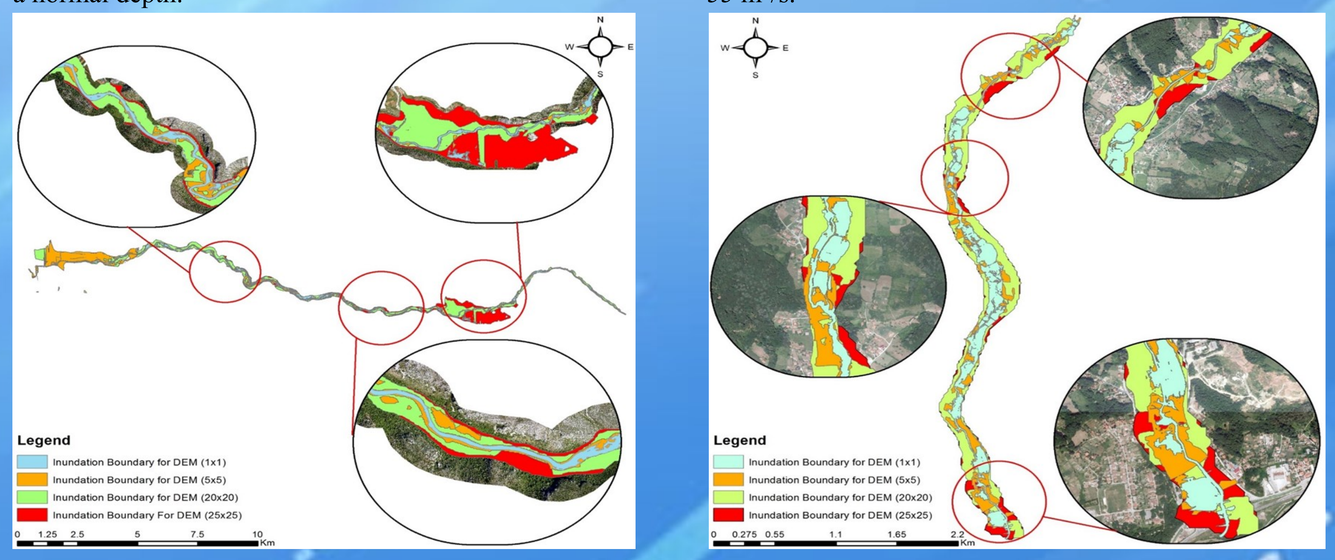

Figure 3. Inundation boundary resulting from the four different DEMs (Bregava river in the left, Jošavica river in the right)

Overlapping the maps of the inundation boundaries resulting from the different models, it is concluded that the use of a low-resolution DEM overestimates the prone areas as it is shown in the Figure 3.

Next step, RMSE is computed for each DEM with respect to the LiDAR DEM. The RMSE calculated for the two rivers selected for this study increases with decreasing the DEM-resolution as shown in Table 1. And the magnitude of the RMSE is found to be related to the size of the study area.

Table 1. The Root Mean Square Error with respect to LiDAR DEM

DEM-resolution	RMSE
Bregava river section	
DEM 1x1m	Ref.
DEM 5x5m	2.2 m
DEM 20x20m	6.5 m
DEM 25x25m	14.2 m
Joševica river section	
DEM 1x1m	Ref.
DEM 5x5m	1.3 m
DEM 20x20m	3.2 m
DEM 25x25m	4.5 m

The results of the RMSE were compared with the results obtained overlapping the inundation boundaries and it confirms the fact that using a coarser DEM-resolution leads to overestimation of the flood prone areas for both type of rivers but in same time comparing to the existing AFA polygon which is the result from the Preliminary Flood Risk Assessment (PFRA). for some zones the increase is relatively acceptable.

Risk maps

The results of these maps (Figure 4) show that using a coarser DEM-resolution might increase the flood risk in certain areas which could lead to a misinterpretation of the real flood damage and that's mainly related to the increase of the flood prone areas without considering the water surface elevation.

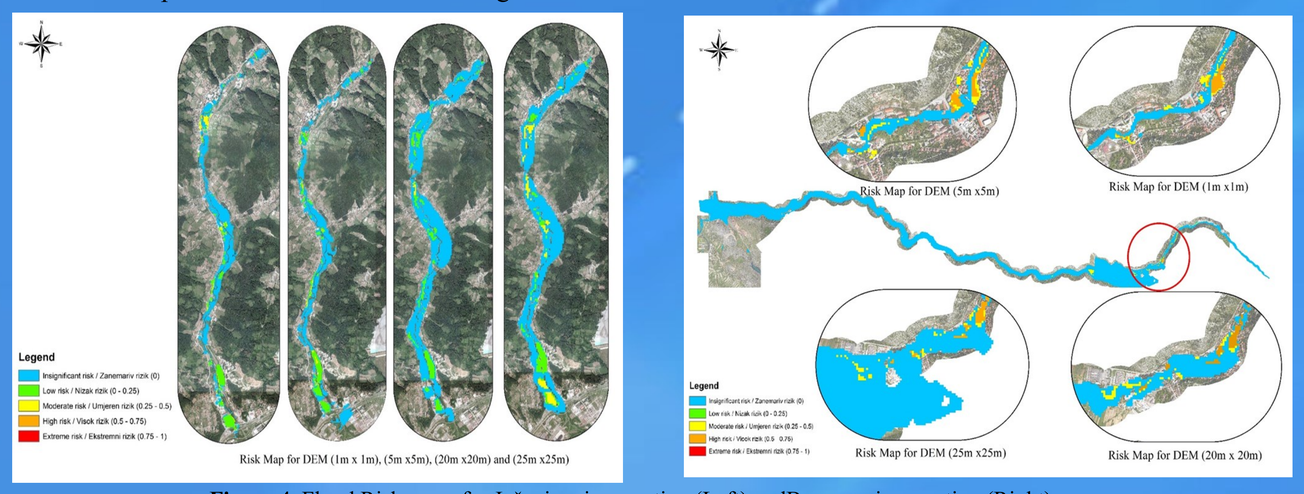

Figure 4. Flood Risk maps for Joševica river section (Left) andBregava river section (Right)