Flood hazard mapping by integrating airborne laser scanning data, high resolution images and large scale maps: a case study

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The assessment and management of flood risks framework impose the mapping of flood hazard in potential flood risks areas. Floods in urban environments may happen due to rainfall extreme events and be exacerbated by saturated or impervious surfaces. Flood risk is greater in urban areas.

The urban flood inundation modelling needs high resolution and accurate geospatial data and also measurements of water depth and flood extent to validate the model. The methods to integrate high resolution geospatial data to derive input to the flood models and their impact on the model output are still a research issue. These topics are addressed in this work.

The flood inundation model was applied to a small urban catchment within Vila Nova de Gaia city, at the northern part of Portugal, where it has been observed several flood events in a recent past. The area to be modelled comprises a rectangle of 0.8 km × 1.0 km. The topography, topology and land cover of the study site were characterized with the help of a 1 m x 1m resolution LiDAR Digital Surface Model (DSM), high resolution colour infrared images with a pixel of 0.5 m and digital maps at 1:2000 scale with the buildings locations, road network and land use classes.

The LISFLOOD-FP, Version 4.5, a raster-based model for the modelling of urban flood inundation developed by Bates & De Roo, (2000) was used in this work. Several improvements to the model were carried out subsequently (Horritt & Bates, 2001; Hunter et al., 2005).

The upstream boundary is a hydrograph calculated by the Hydrologic Engineering Center - Hydrologic Modelling System (HEC-HMS) model, version 3.5. In order to determine the peak flood discharge the Soil Conservation Service method is applied as a consistent methodology for ungauged small basins. The design hydrograph was built from the 100-year return period dimensionless hydrograph.

The flood inundation models require input data such as terrain morphology and friction coefficients, which have to be derived from raw data by using adequate methods. The Digital Terrain Model (DTM) is produced by filtering non-terrain features, such as vegetation and buildings, from the Digital Surface Model (DSM) followed by the spatial interpolation among the terrain points. A normalized Digital Surface Model (nDSM) gives the non-terrain feature height values and results from subtracting the DTM to the DSM.

The vegetation is extracted from the high-resolution images by the Normalized Difference Vegetation Index. The produced vegetation map is intersected with the nDSM to obtain the vegetation height. In this new map, the cells with a height value greater than 2 m are removed to obtain a Digital Surface Flow Model (DSM_{f1}). Other Digital Surface Flow model (DSM_{f2}) is produced which contains the buildings. This is done by inserting the buildings locations, computed from topographic maps into the DTM . The areas demarked as buildings are raised by 12 m.

The spatially distributed friction coefficients are assigned to the land use classes extracted from large scale maps. For this study, the values of each friction class were taken from literature (Chow, 1959; Van der Sande *et al*., 2003; Schubert *et al*., 2008).

The dynamic flood wave was simulated and the effect of topography and friction coefficients on the output of the flood model, i.e., flood extension and water depths was tested. Three simulations were made with different input data combination (Table 1), the DSM_{f1} is combined with both spatially distributed and stationary friction coefficients whereas the DSM_{f2} is combined solely with the spatially distributed friction coefficient. The stationary friction coefficient is computed by averaging the friction coefficients values over the whole area.

Table 1 - Inputs used for the simulations.

Simulation No.	Topography	Friction coefficient
1	DSM_{f1}	Spatially-distributed
2	DSM_{f2}	Spatially-distributed
3	DSM_{f1}	Stationary

The simulations 1, 2 and 3 present inundation extent of respectively 38997m^2, 44365m^2 and 35107 m^2. The extent of inundated area according to predicted water depth is presented in Table 2.

Table 2 – Extent of inundated area according to predicted water depth (m^2).

Simulation No.	0.0 - 0.5m	0.5 - 1.5m	>1.5m
1	35934	1760	1303
2	41331	1734	1300
3	32061	1746	1300

As the results point out, the introduction of other input information into the terrain morphology, such as the buildings, alter substantially the output of the model. This is more evident when estimating the inundated area extent according to predicted water depth. Similar conclusions may be draw when comparing the input related with the friction coefficients values. It may be then conclude that terrain data available from LiDAR systems are sufficiently accurate for simulating depth and flood extent in urban areas when combined with digital maps and high resolution imagery. The best way to reduce uncertainly in flood inundation model predictions is to improve the process of extracting the model input data. Remotely sensed data and digital map provide ways of estimating the friction coefficients, but considerable uncertainly still remains. Of foremost importance is the calibration of flood inundation model challenged by the reduced number of records available in urban areas.

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