UNI- AND MULTI-VARIABLE MODELLING OF FLOOD LOSSES: EXPERIENCES GAINED FROM THE SECCHIA RIVER INUNDATION EVENT

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Outstanding Student Poster & PICO Contest

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STUDY AIM

Are uni-and multi-variable models reported by the literature suitable for quantifying flood losses in geographical and socio-economic contexts that differ from those for which they were originally developed?

We addressed the open problem of transferability of empirically obtained damage models into different contexts. Because of the lack of reliable literature damage models in the Italian context, we derived uni- and multi-variable damage models from post-event data collected after a recent flood in Italy; then, we compared their performance in estimating direct economic damages with those of literature damage models, developed in different socio-economic and geographical contexts.

STUDY AREA AND FLOOD EVENT

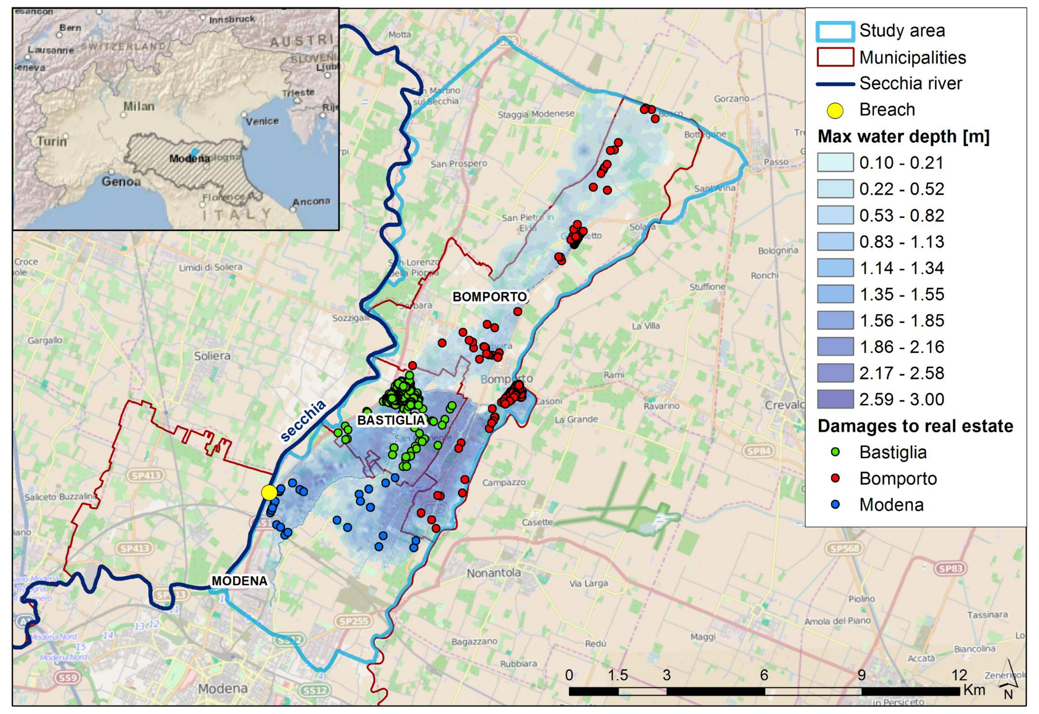

Fig. 1. Study area: Secchia river with breach point (yellow dot) and municipalities of interest (Bastiglia, Bomporto and Modena). Blue area indicates the maximum water depths simulated by the 2D model and the green, red and blue points show the geocoded damaged real estate, divided as per municipalities.

- Date and time: 19/01/2014, 06:30 am
- Breach location: S. Matteo (Modena, Italy; see Fig. 2)
- Estimated overflowed volume: **36.3 ÷ 38.7 · 10^6 m³**
- Total estimated flooding damages: **500 million €**
- Flooded area: **52 km²** (mainly including the municipalities of **Bastiglia**, **Bomporto** and the Northern part of **Modena**, which remained flooded for more than 48 hours; see Fig. 3)
- Reconstruction of the inundation event: Telemac-2D finite element numerical model (unstructured computational mesh with elements of variable size from 1 to 200 m in the flat zones, covering a study area of 112 km² area; see Fig. 1 and 4)

Fig. 2. Pictures of the breaching point on the right embankment of the Secchia river

Fig. 3. Pictures of the flooded area

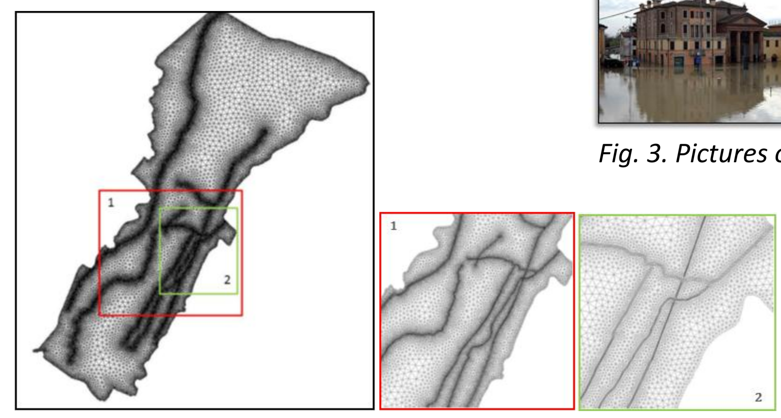

Fig. 4. Unstructured mesh for the 2D model, showing different mesh sizes in order to reproduce topographic singularities.

AVAILABLE DATA

1330 forms available, filled by citizens about observed damages to **real estate** and **movable properties**. All data were geocoded with a GIS procedure and merged with additional predictive variables, retrieved by external sources or simulated by means of the 2D model.

Variable	Description	Obs.	Sim.	Ext. sources
max_w_depth	Maximum water depth [m]		●	
max_vel	Maximum water velocity [m/s]		●	
fl_dur	Flood duration [h]		●	
area	Building area [m2]	●		
build_val	Building value [€/m2]			●
str_type	Structural typology [-]	●		
abs_dam_real_est	Absolute damages to real estate [€]	●		
rel_dam_real_est	Relative damages to real estate [-]	●		
abs_dam_mov_prop	Absolute damages to movable properties[€]	●		

Table 1. Summary of the considered variables and their sources.

EMPIRICAL DAMAGE MODELS

- *Uni-variable models (water depth as the only explanatory variable)*:
  - **SE (Secchia Empirical)**, obtained by combining the median value for the observed data for considered water depth classes of 25 cm;
  - **SSRRs (Secchia Square Root Regression)**, obtained from the relationships between observed relative losses and: maximum water depth (SSRR_wd), maximum water velocity (SSRR_wv), building area (SSRR_ba), taken one at a time.
- *Multi-variable model (combination of several explanatory variables)*:
  - **SBTs (Secchia Bagging Decision Trees)**, which considers an ensamble of regression (decision) trees, built with the Random Forest algorithm creating multiple data set samples using the resampling bootstrap method. Losses prediction is made by recursively sub-dividing each bootstrap replica data set into smaller parts, in order to maximize the predictive accuracy, allowing the evaluation of the variable importance in the damage process. (Merz et al., 2013; Schröter et al., 2014; see Fig. 7).

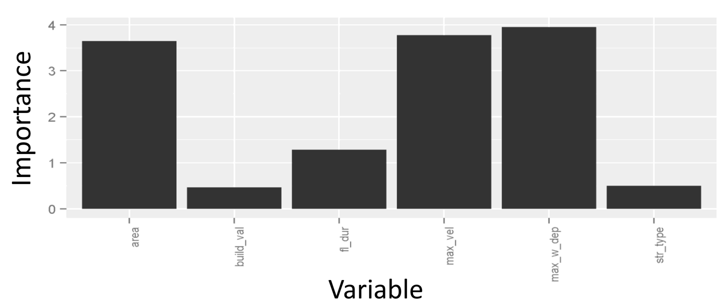

Fig. 7. Importance of predictive variables considered in the SBTs model

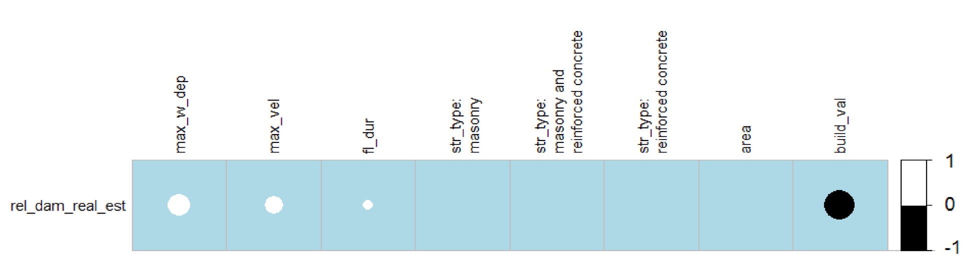

Fig. 8. Spearman correlation of the relative losses to real estate and the predictive variables. Empty boxes represent statistically insignificant correlation (lower than 5% significance level).

RESULTS

PERFORMANCES OF UNI- AND MULTI-VARIABLE MODELS FOR ESTIMATING FLOOD LOSSES TO REAL ESTATE

Estimation of the relative losses to real estate by means of both the well known and widely used literature uni-variable damage models (Huizinga et al., 2007; Jongman, et al, 2012, Thieken et al., 2008) and the empirical uni- and multi-variable ones; comparison between estimated and observed losses values in terms of MBE, MAE, RMSE and differences of absolute total damages.

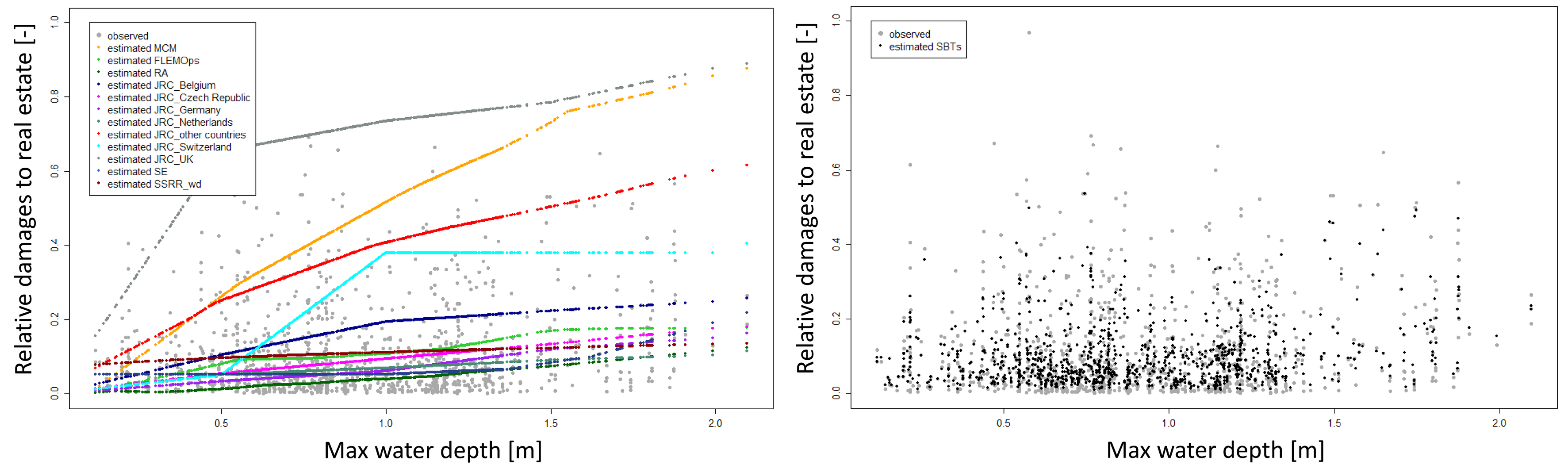

Fig. 5. Relative damages to real estate estimated with the literature and the empirically developed uni-variable models (colored dots, left panel) and multi-variable model (black dots, right panel). Grey dots in both panels represent the observed damages.

	MBE [-]	MAE [-]	RMSE [-]	Differences between total observed and total estimated damages [million €]	
SBTs	-0.012	0.034	0.062	1.5	GOOD
SSRR_wd	0.000	0.089	0.124	-0.8	GOOD
SSRR_ba	0.000	0.089	0.124	-0.2	GOOD
SSRR_wv	0.000	0.090	0.124	-0.9	GOOD
FLEMOps	-0.003	0.089	0.125	-0.3	GOOD
JRC_Czech Republic	-0.022	0.085	0.127	2.5	GOOD
JRC_Netherlands	-0.043	0.082	0.131	5.7	FAIR
SE	-0.048	0.080	0.132	6.3	FAIR
JRC_Germany	-0.046	0.082	0.133	6.1	FAIR
JRC_Belgium	0.056	0.119	0.142	-8.8	FAIR
RA	-0.071	0.087	0.143	9.8	FAIR
JRC_Switzerland	0.149	0.196	0.232	-22.5	POOR
JRC_other countries	0.256	0.272	0.300	-38.4	POOR
MCM	0.350	0.364	0.406	-52.1	POOR
JRC_UK	0.585	0.586	0.607	-86.6	POOR

Table 2. Performance of different uni- and multi-variable models in estimating relative damages to real estate, compared to the observed ones. Models are sorted in terms of increasing RMSE.

TRANSFERABILITY OF THE EMPIRICAL DAMAGE MODELS IN SIMILAR CONTEXT

Assessment of the transferability of the empirical uni- and multi-variable damage models in similar socio-economic and geographical contexts.

Calibration on Bomporto's data set (392 records) and application to Bastiglia

	MBE [-]	MAE [-]	RMSE [-]
Bo_BTs	0.089	0.136	0.155
Bo_SRR_wd	0.000	0.085	0.118

Calibration on Bastiglia's data set (887 records) and application to Bomporto

	MBE [-]	MAE [-]	RMSE [-]
Ba_BTs	-0.006	0.080	0.115
Ba_SRR_wd	0.000	0.091	0.126

Tables 3 and 4. Performance of empirically developed uni- and multi-variable models in estimating relative damages to real estate in different contexts, compared to the observed ones.

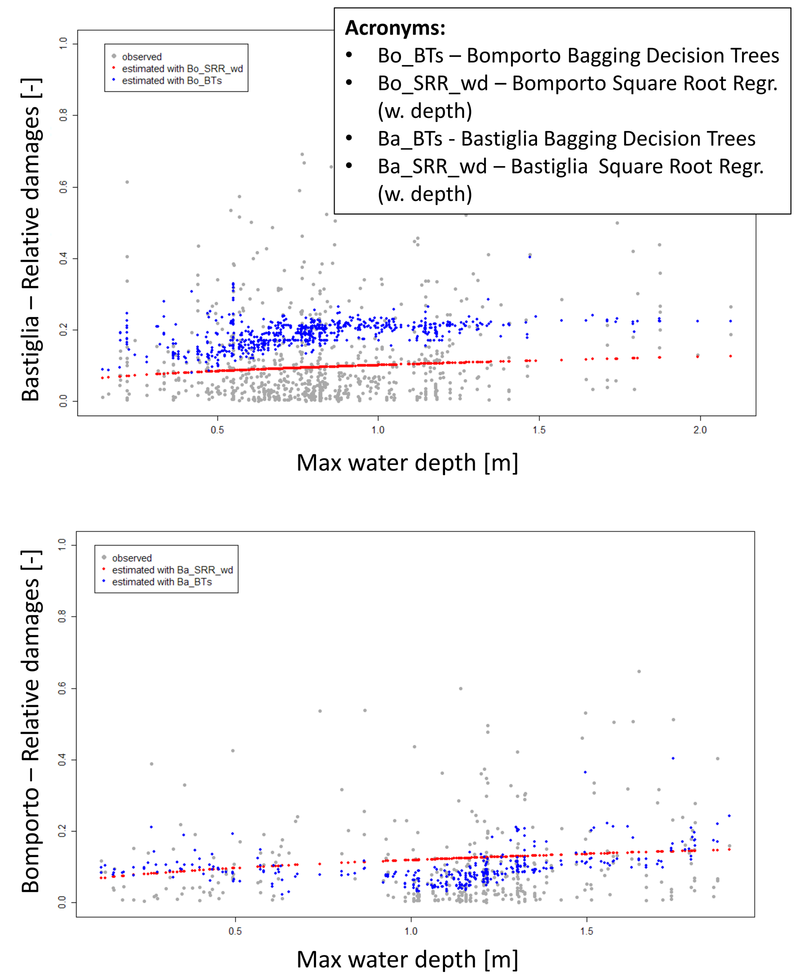

Fig. 6. Top panel: Bastiglia relative damages to real estate estimated with SRR_wd model (red dots) and the BTs model (blue dots), both calibrated on Bomporto's data set; Bottom panel: Bomporto relative damages to real estate estimated with SRR_wd model (red dots) and the BTs model (blue dots), both calibrated on Bastiglia's data set. In both panels, grey points represent the observed data.

CONCLUSIONS

- **Uni- and multi-variable models developed on the basis of observed data set estimate more accurately flood losses than literature ones**
- **The multi-variable approach slightly outperforms the uni-variable one for this specific case study**
- **The results highlight the need for a comprehensive collection of post-event data, aiming at validating existing models, or developing new ones in case existing literature models are proven to be unreliable**
- **Literature damage models, originally developed for specific socio-economic and geographical contexts, should be prudently exported to different contexts**

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