Supplementary material

Model parameter sensitivity analysis of 2D overland flow

Methodology

In this study, sensitivity analysis of model parameters, namely infiltration rate (Ks), imperviousness, and Manning roughness coefficient (n), was performed to provide an understanding of the behaviour of key model parameters. This analysis does increase the confidence about the model performance and its predictions (Kleidorfer et al. 2009).

Sensitivity analysis of the model parameters was undertaken for each considered parameter, varying its value between the selected ranges while keeping all the others unchanged. Three important parameters in the 2D overland flow model, including Ks, n, and imperviousness, were considered. These parameters were obtained by correlating their values with land use and soil type/texture information from previous studies (Aldridge and Garrett 1973; Chow 1964; Liu and De Smedt 2004; Plasschaert 2019). Six categories of land use were adapted to the study area. Two scenarios of model parameters (i.e. minimum and maximum values) for each parameter were examined in the flood model, as presented in Table 1.

Table 1. Selected parameters for sensitivity analysis of model performance.

Land use / cover types	Imperviousness (%)		Manning roughness coefficient n*		Infiltration rate Ks** (mm/h)	
	Imp. min.	Imp. max.	n min.	n max.	Ks min.	Ks max.
Road	100	100	0.013	0.016	0	0
Building	100	100	0.011	0.017	0	0
Residential area (high density)	80	100	0.077	0.144	12.99	22.59
Residential area (low density)	20	40	0.082	0.159	1.69	25.04
Agricultural area	2	10	0.144	0.35	3.77	29.56
Water	0	0	0.05	0.05	1000	1000

* Obtained and adapted from Aldridge & Garrett (1973), Chow (1964), Liu and De Smedt (2004)

** Obtained from Plasschaert (2019)

Results and discussions

The model parameter sensitivity was assessed for the two flood events on 9 October 2017 and 16 July 2018. Impact results are summarized in Table 2 and Table 3. For the infiltration rate *Ks*, the impact on model performance was more obvious in the peri-urban areas, where part of the agricultural land still exists, than in the city center, where most of land use has become residential and infrastructural. Figure 1 presents the water depths at 3 observation sites. The simulation with no infiltration, where the soil at the surface zone is saturated and no more water can be absorbed, had a larger flood extent and a higher flood depth compared to those with the maximum and minimum *Ks* values considered (Table 1). When the minimum and maximum Ks values were used, the flood extent decreased by 7.6% and 13.7% respectively in comparison with the case of no infiltration. The impact of changing Ks is limited, as, the Ks range is relatively small. The survey by Plasschaert (2019) showed the prominence of clayey soils in the flood plain that all had low Ks values.

For the Manning roughness coefficient *n*, the simulated flood extent with the minimum surface roughness (2.15 km^2) was slightly larger than that with the high roughness (2.13 km^2). When the impact of n was examined at various water depths, the increase of water depths was small (less than 1% and less than 1 cm).

With respect to imperviousness, the flood extent decreased by 16.1% (from 2.3 to 1.93 km^2) when the imperviousness changed from the maximum to the minimum imperviousness. The impact of imperviousness was larger than for Ks and n: the water depths between the two imperviousness scenarios ranged from approximately 1 to 3 cm in comparison to less than 1 cm for the other two parameters. The sensitivity of the imperviousness is illustrated in Figure 2 for the heavily flooded area in the city center of Ha Tinh. The flood maps show a noticeable decrease in flood depth and flood extent between the minimum and maximum imperviousness. This finding is in line with Kleidorfer et al. (2009).

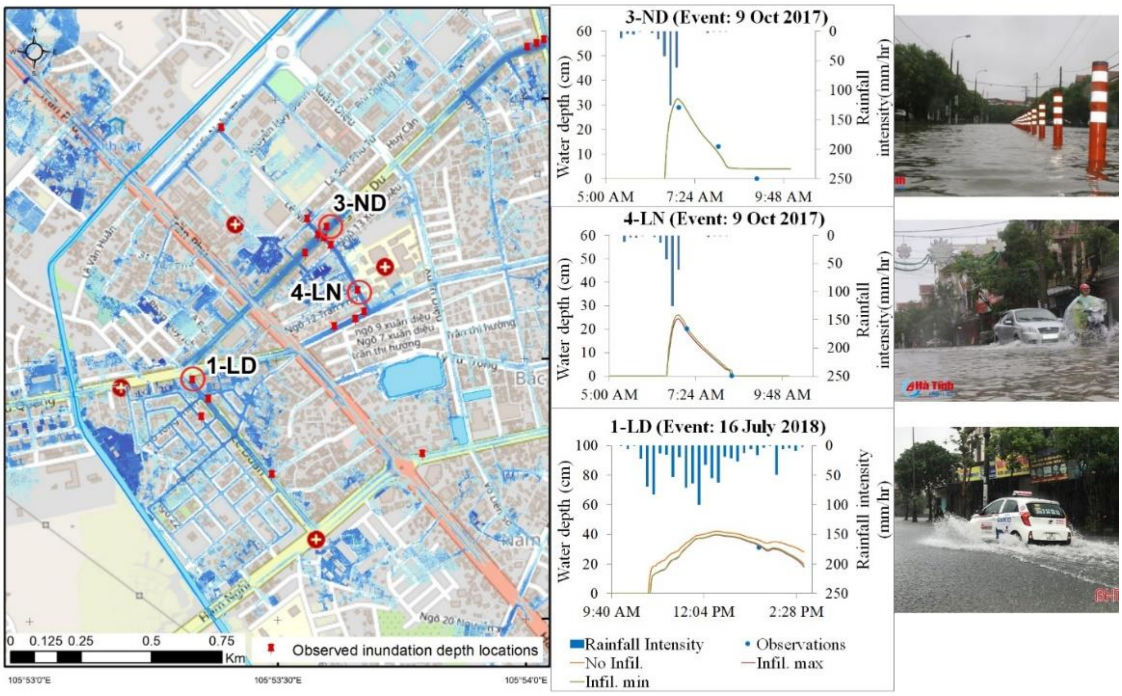

Figure 1. Infiltration sensitivity analysis: simulation results on water depths for different infiltration rates and comparison with observed water levels and the corresponding photos at three specific locations in the city center obtained from Ha Tinh newspaper for two simulated flood events in 9 Oct 2017 (https://baohatinh.vn/xa-hoi/video-mua-lon-duong-pho-ha-tinh-ngap-nhu-song/141831.htm) and 16 July 2018 (https://baohatinh.vn/xa-hoi/mua-lon-nhieu-tuyen-giao-thong-tp-ha-tinh-ngap-sau/158116.htm). Assessed 10 Oct 2019.

Table 2. Impact of model parameters on flood extent.

Infiltration (Ks)		Imperviousness		Manning roughness coefficient (n)	
Value	Inundation area (km^2)	Value	Inundation area (km^2)	Value	Inundation area (km^2)
No infiltration	2.48				
Ks min	2.29 (↓7.6%)*	Imp. min	1.93 (↓16.1%)**	n min	2.15
Ks max	2.14 (↓13.7%)*	Imp. max	2.3	n max	2.13

(*) Percentage inside the bracket means % change of inundation area compared with the simulation with no infiltration

(**) Percentage decrease of inundation area compared with Imp. Max

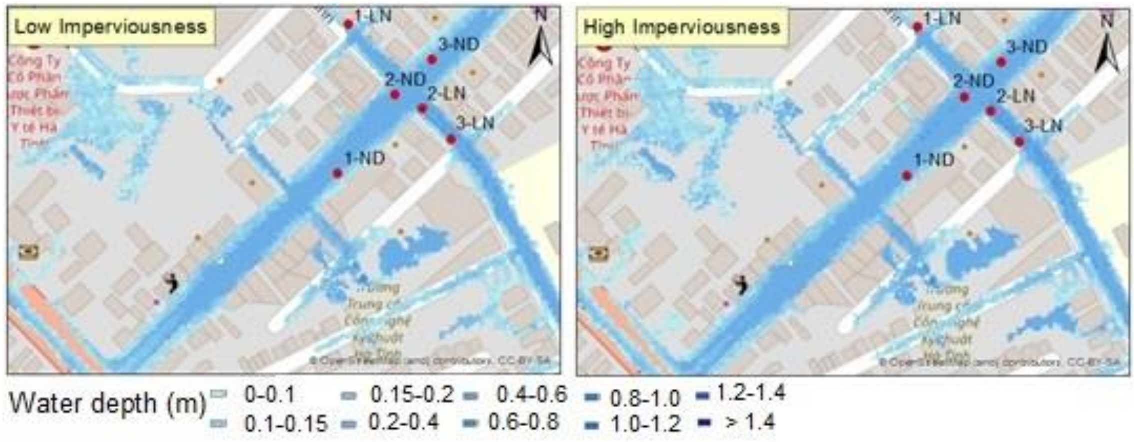

Figure 2. Imperviousness sensitivity analysis: Comparison of flood maps for the heavily flooded area in the city center.

Table 3. Impact of model parameters on inundation depth at observation locations in the city center.

Obs. Point ID	Simulated flood depth (cm)									
	Infiltration (Ks)				Imperviousness			Manning roughness (n)		
	No Infil.	Ks min	Ks max	Diff.*	Imp. max	Imp. min	Diff.*	n max	n min	Diff.*
2-XVNT	31.49	33.13	32.69	*0.44*	33.12	31.78	*1.34*	33.09	32.69	*0.40*
3-XVNT	40.79	40.44	40.01	*0.43*	40.37	39.22	*1.15*	40.43	40.01	*0.42*
5-ND	46.40	38.52	38.23	*0.29*	39.20	37.20	*2.00*	39.35	38.23	*1.12*
3-HTLO	30.46	29.87	29.57	*0.30*	30.36	28.57	*1.79*	29.73	29.57	*0.16*
1-LD	36.12	33.09	32.42	*0.67*	33.70	31.00	*2.70*	33.30	32.42	*0.88*
2-LD	44.20	41.21	40.54	*0.67*	41.80	39.13	*2.67*	41.43	40.54	*0.89*
3-LD	20.37	18.60	18.10	*0.50*	18.94	17.03	*1.91*	18.88	18.10	*0.78*
1-LN	7.36	6.75	6.46	*0.29*	7.23	5.50	*1.73*	6.62	6.46	*0.16*
1-NCT	31.04	29.94	29.35	*0.59*	30.40	28.26	*2.14*	29.57	29.35	*0.22*
2-NTC	36.42	35.19	34.55	*0.64*	35.41	33.55	*1.86*	35.90	34.55	*1.35*

(*) Diff.: is the difference of flood depth between maximum and minimum values of model parameters

References

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