Pluvial flooding in urban areas: Parsimonious hazard mapping for a case study in Berlin, Germany

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Natural Hazards and Risks in a Changing World

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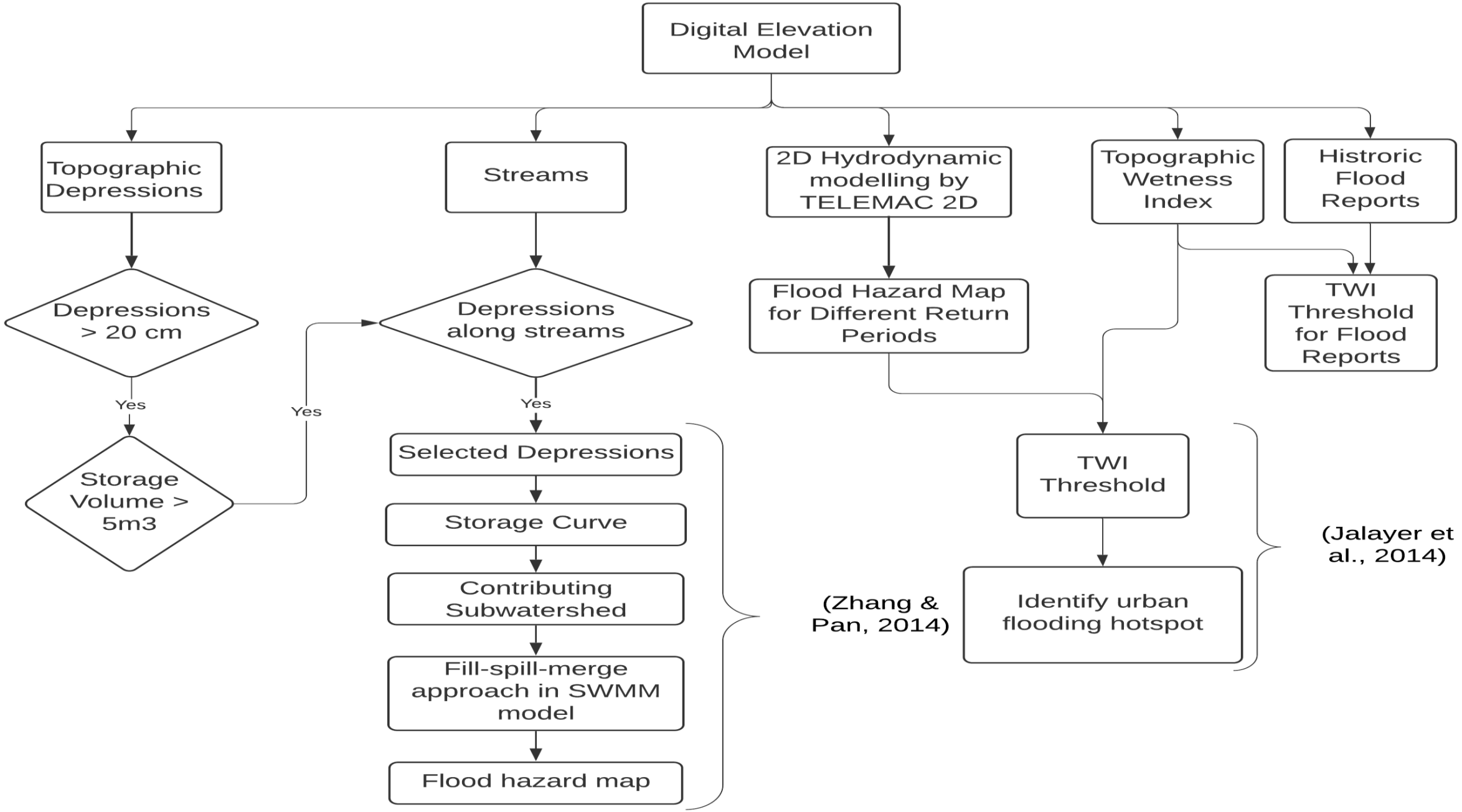
Background

- Urbanization and the intensification of extreme rainfall events are increasing pluvial flooding frequency in many cities.
- Hydrodynamic models are accurate but require high computation cost.
- Identification of flood prone areas can be considered as one of the fundamental initial steps in strategic urban planning.

Study Objectives:

- Applying **fill-spill-merge** approach in urban area and compare the resulted floodplain with the 2D hydrodynamic model results.
- Investigating if **topographic indices** can identify flood prone areas by analyzing the data from **1500 reported historic flood location**.
- Use **geomorphic approaches** for delineating flood prone areas.


Digital Elevation Model
Topographic Depressions
Streams
2D Hydrodynamic modelling by TELEMAC 2D
Topographic Wetness Index
Historic Flood Reports
Depressions > 20 cm
Depressions along streams
Flood Hazard Map for Different Return Periods
TWI Threshold for Flood Reports
Yes
Yes
Yes
Storage Volume > 5m3
Selected Depressions
Storage Curve
Contributing Subwatershed
Fill-spill-merge approach in SWMM model
Flood hazard map
TWI Threshold
Identify urban flooding hotspot
(Zhang & Pan, 2014)
(Jalayer et al., 2014)

Topographic Wetness Index (TWI)

TWI was proposed by (Kirkby, 1975) :

$$TWI = \ln(a/\tan b)$$

Where:

- a is local upslope area draining through a certain point per unit contour length
- b is local slope in radians

- **TWI and depression depth** are useful to specify the location of pluvial flooding (Kelleher & McPhillips, 2019)

We classified TWI as follow:

- **Low:** minimum ≤ Low < mean
- **Medium:** mean ≤ Medium < mean + std
- **High:** mean + std ≤ High < maximum

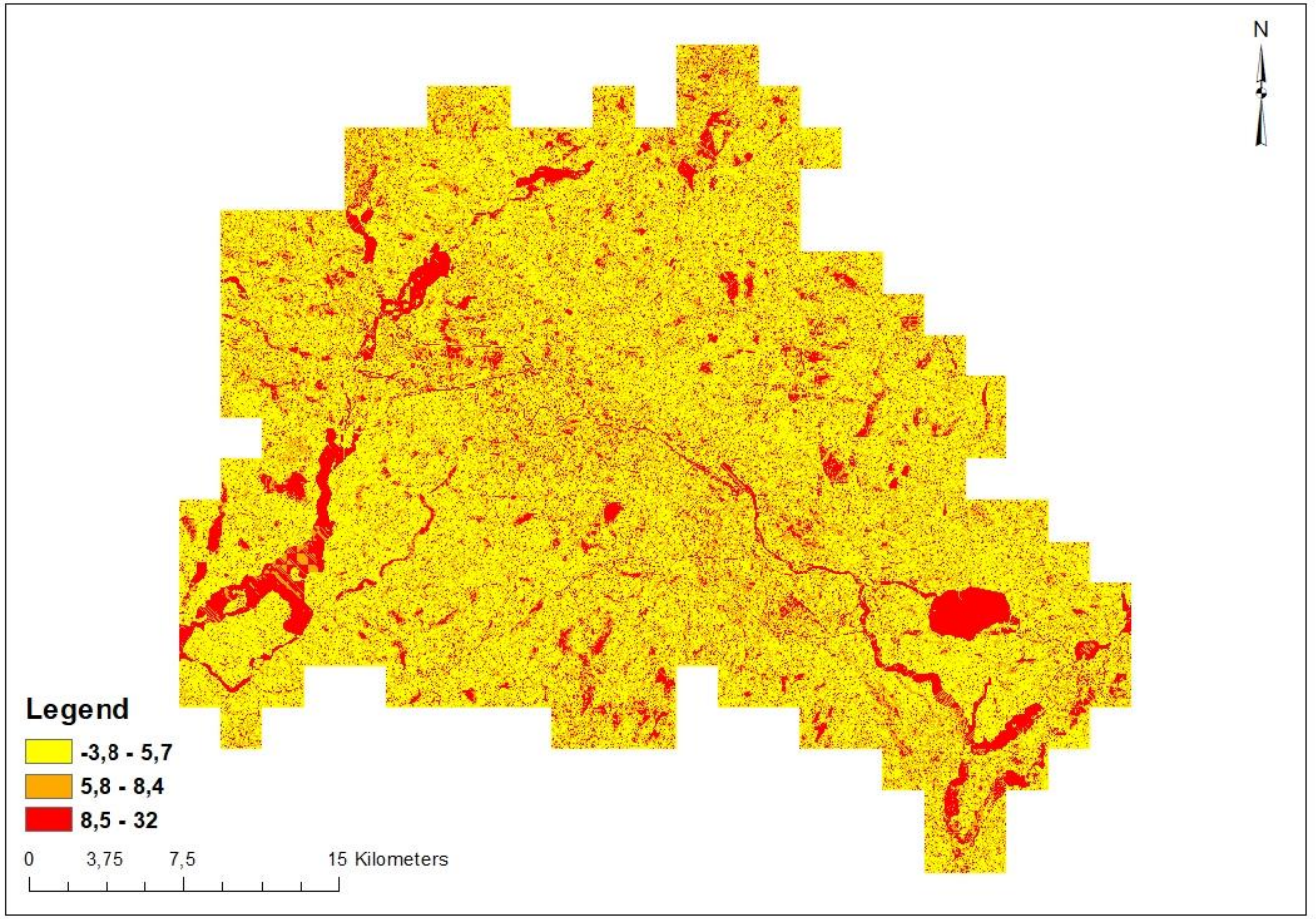
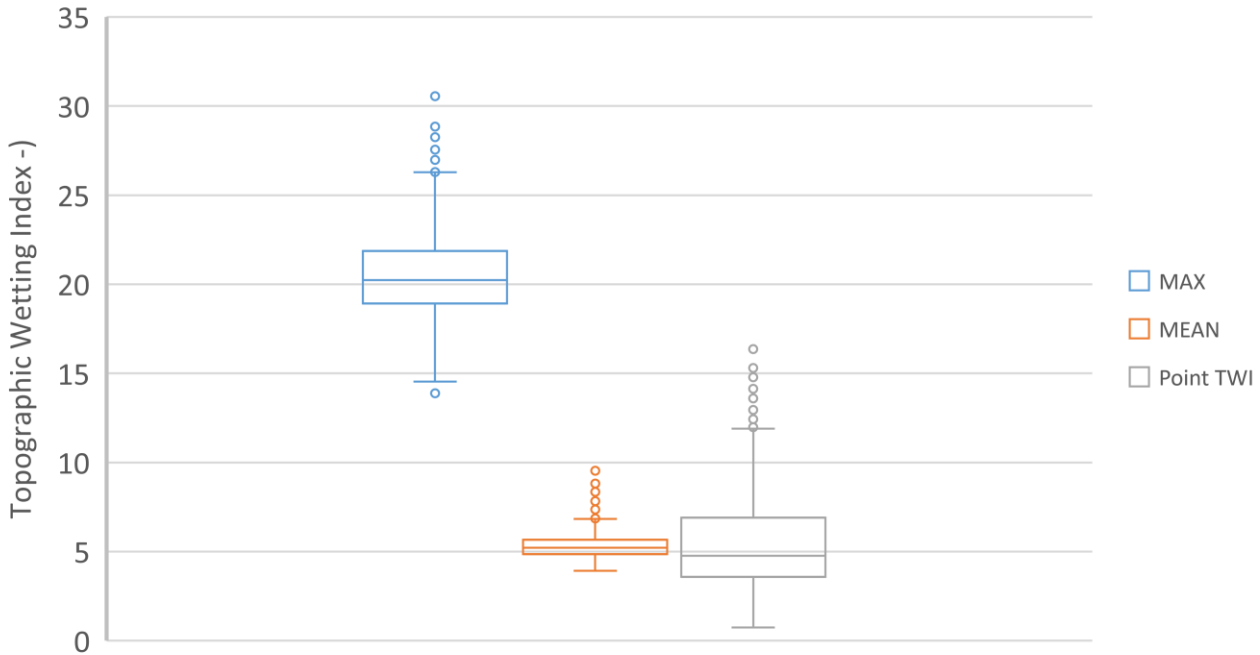
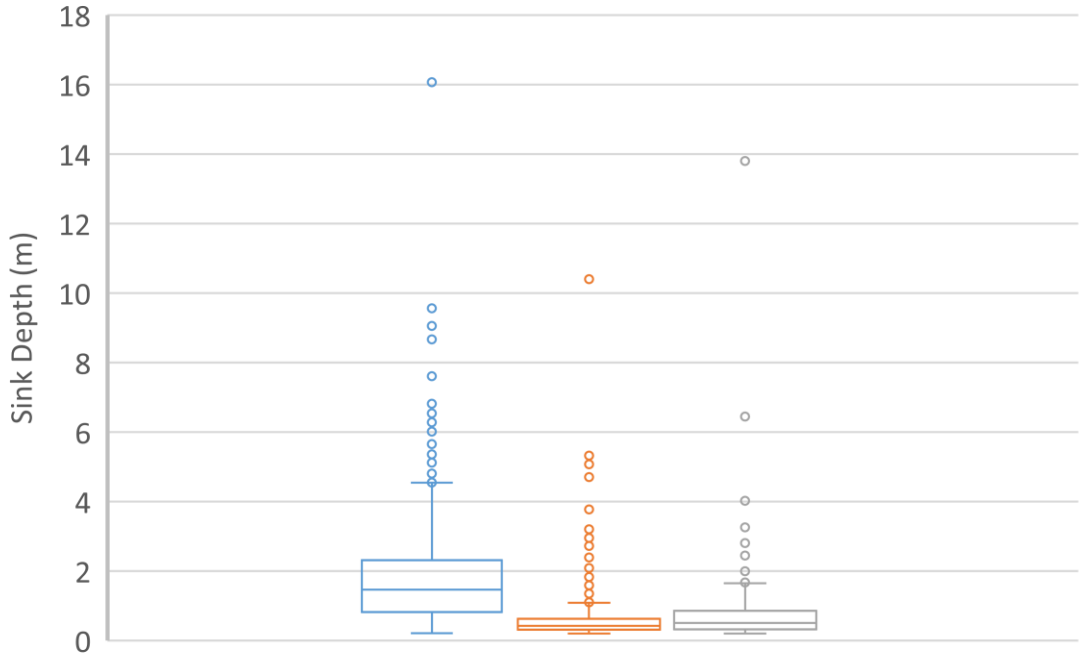


Fig. TWI for Berlin based on high resolution DEM (1x1m)

Topographic Wetness Index (TWI)

- TWI and sink depth values for **1500 Historic Flood Reports** in Berlin.
- We estimated the TWI and sink depth values at the point location, and maximum and mean values in a 100m buffer distance around the flood report point as the point locations aren‘t accurate.
- Majority of the reported flood locations are in **medium and high TWI categories.**





Fill-spill-merge Approach

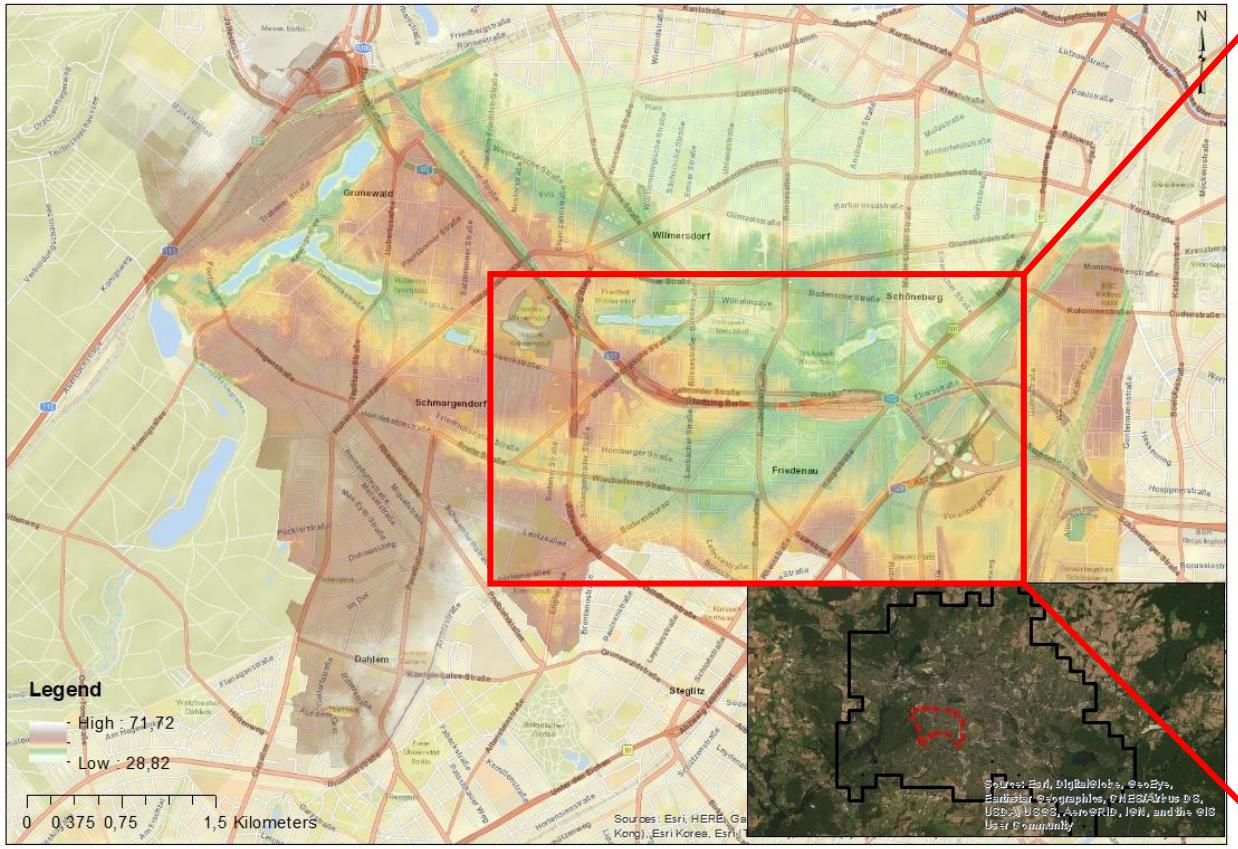


Fig. Study area in Berlin

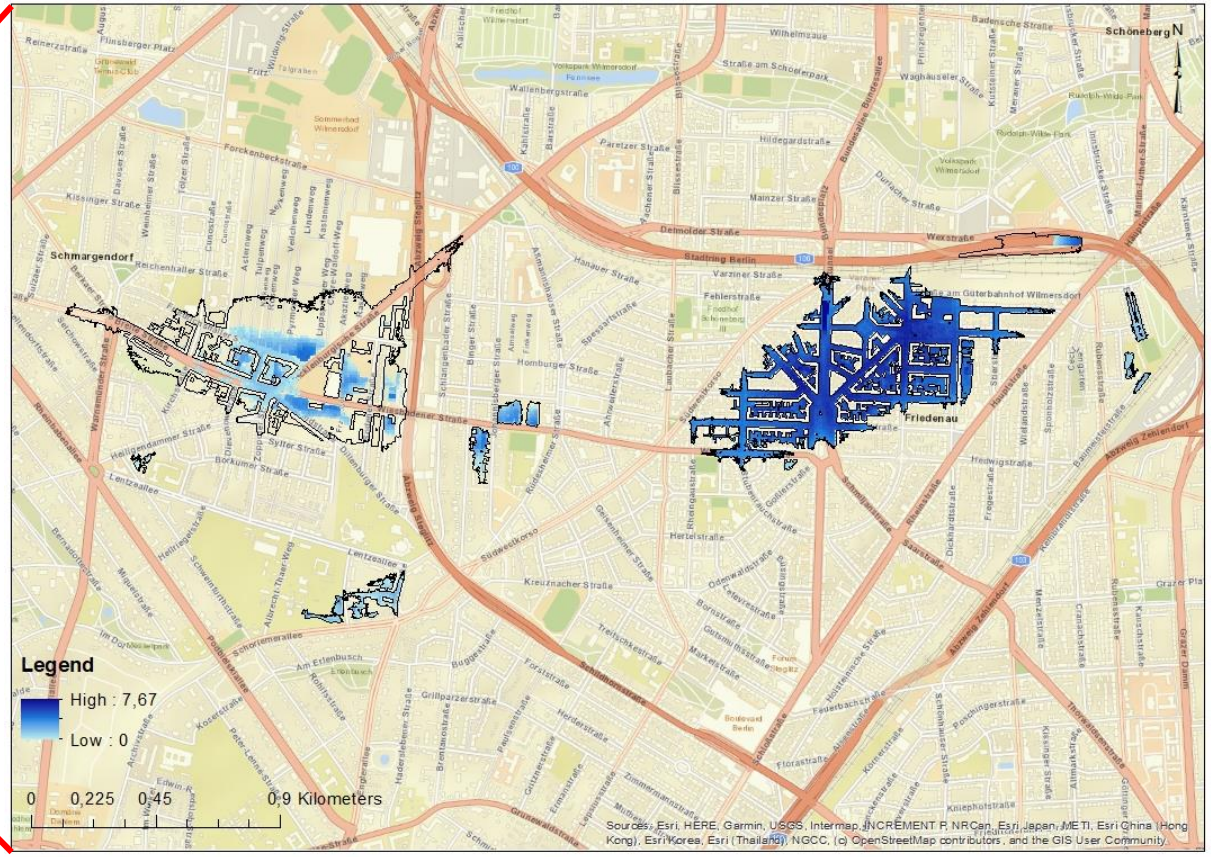


Fig. Floodplain within the selected depressions based on Fill-spill-merge approach for a 50mm rainfall

Fill-spill-merge Approach

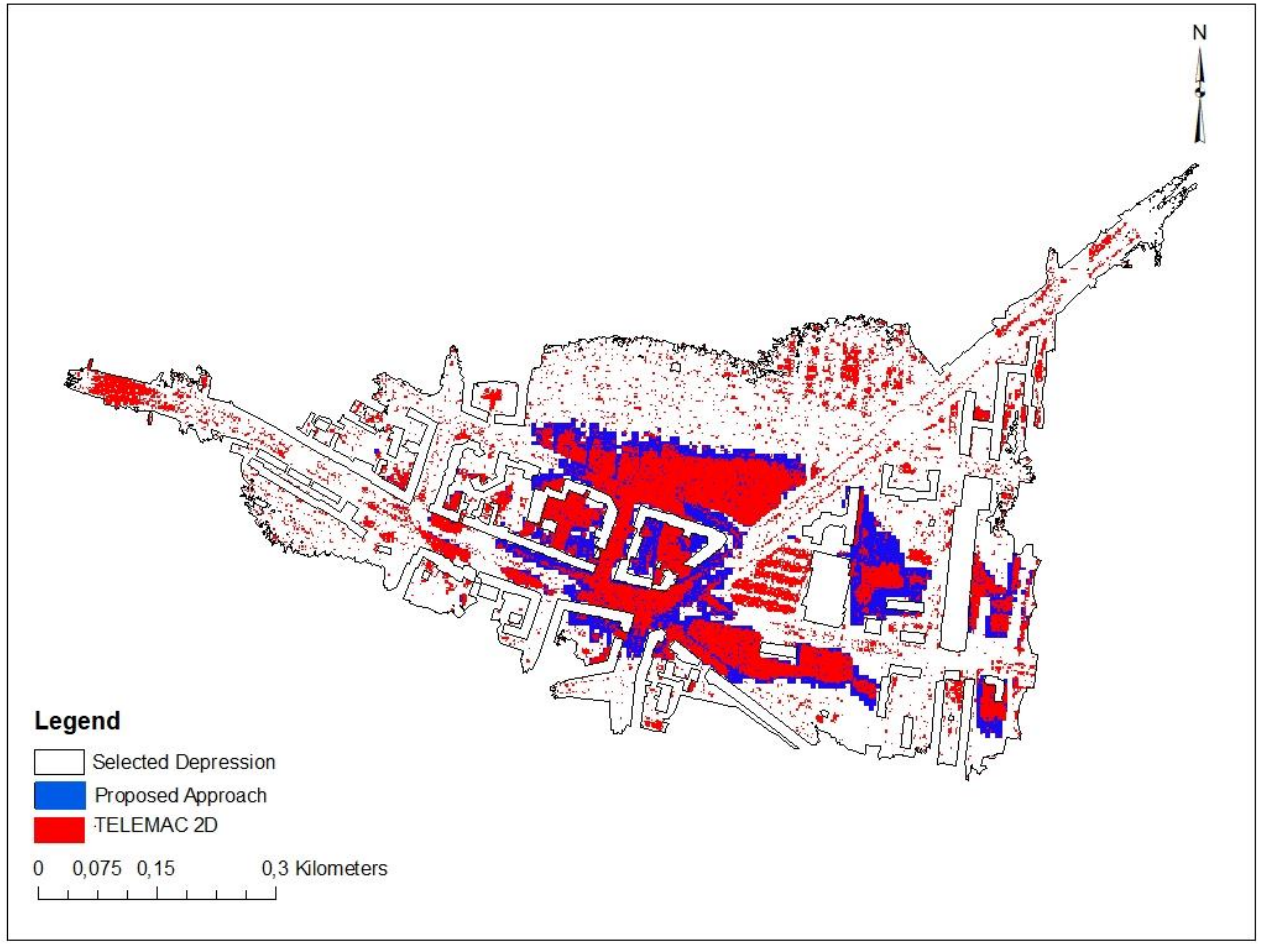


Fig. Floodplain from TELEMAC 2D and Fill-spill-merge approach

		Model Prediction (Fill – spill- merge)	
		Flood	No Flood
Standard Truth (TELEMAC 2D)	Flood	True Positive	False Negative
	No Flood	False Positive	True Negative

Senestivity (TPR)	63 %
Underestimation(FNR)	37%
Specificty (TNR)	85%
Overestimation(FPR)	15%
Accuracy	79%

Conclusions

- Fill-spill-merge approach is a fast tool for estimating flood plain in urban areas comparing to the 2D hydrodynmaic models.
- Areas with high TWI, have high exposure to urban flooding hazard.

Future Work:

- Produce hazard map for different return periods based on TWI (see (Jalayer et al., 2014))
- Prodcue hazard map based on machine/deep learning.
- Any Recommendations !!

References

- Zhang, S., & Pan, B. (2014). An urban storm-inundation simulation method based on GIS. *Journal of Hydrology*, *517*, 260–268.
- Jalayer, F., De Risi, R., De Paola, F., Giugni, M., Manfredi, G., Gasparini, P., … Nebebe, A. (2014). Probabilistic GIS-based method for delineation of urban flooding risk hotspots. *Natural Hazards*, *73*(2), 975–1001.
- Kirkby, M. J. (1975). Hydrograph modeling strategies. *Process in Physical and Human Geography*, 69–90.
- Kelleher, C. A., & McPhillips, L. E. (2019). Exploring the application of topographic indices in urban areas as indicators of pluvial flooding locations. *Hydrological Processes*.