

# Towards pluvial flooding hazard assessment in an urban environment

Omar Seleem, Maik Heistermann, and Axel Bronstert

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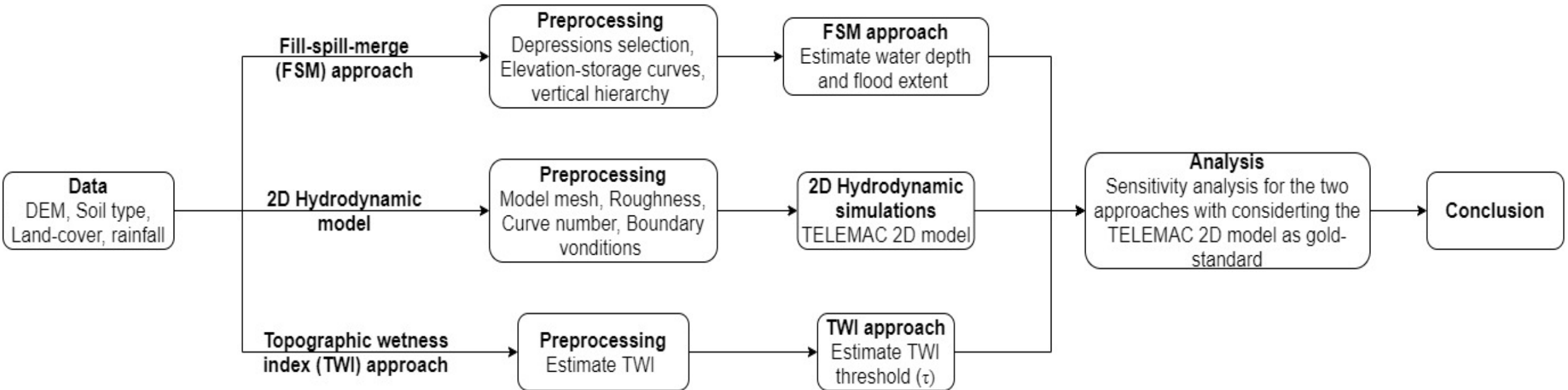
# Background

- ❑ Urbanization and the intensification of extreme rainfall events are increasing pluvial flooding frequency in many cities.
- ❑ Identification of flood prone areas can be considered as one of the fundamental initial steps in strategic urban planning.
- ❑ Hydrodynamic models are most realistic representation of the urban drainage systems but they are not widely applied as:
  - ❑ They are Computationally expensive.
  - ❑ They require large amounts of input data Resource-intensive
  - ❑ Require manual processing

# Research question

- ☐ *How simple approaches can mimic the behavior of 2D-hydrodynamic model with regard to inundation depth and inundated areas.*
- ☐ *Explore the performance of simple approaches depending on the severeness of the rainfall.*

# Overview



# Study Area

- ☐ Berlin city has been repeatedly subject to pluvial flooding in the last decades.
- ☐ The city is characterized by:
  - ☐ Flat terrain.
  - ☐ Decentralized stormwater management system.
  - ☐ Annual precipitation is 591 mm.
- ☐ The flood inventory was used to identify the case study based on the density of the flooded locations.

# Data

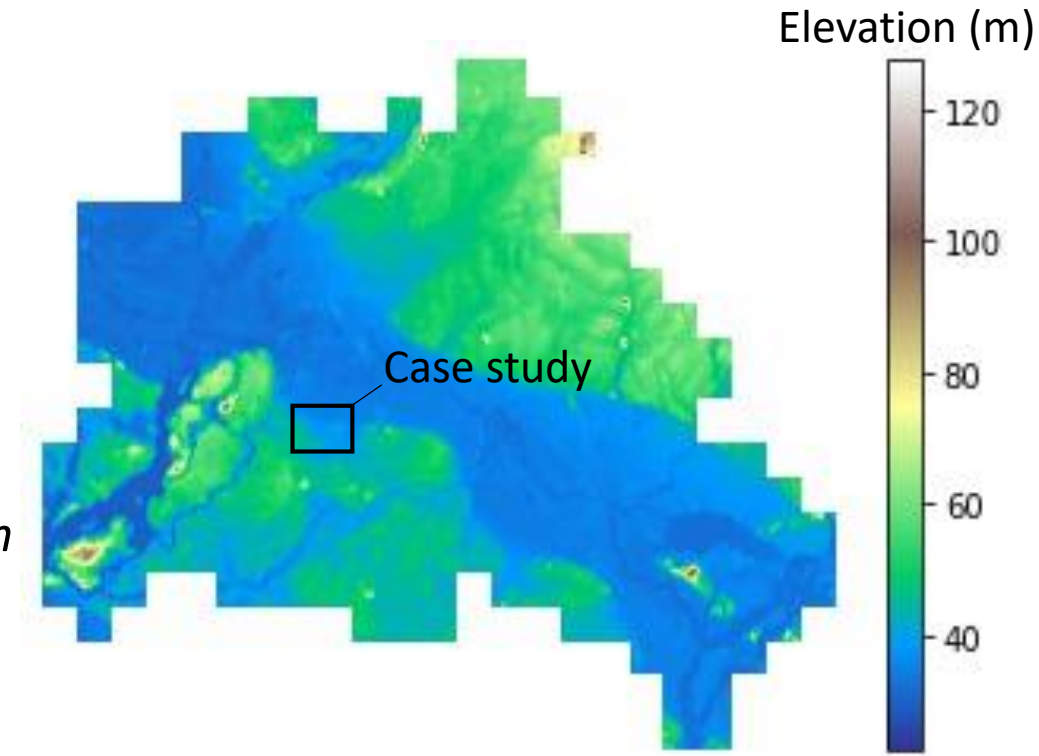
Digital elevation model (*1m x1 m resolution*)

Land cover:

- ❑ *OpenStreetMap data*
- ❑ *Soil hydrologic condition (Ross et al. 2018)*
- ❑ *CN tables to estimate the generated excess runoff*

Rainfall:

*Hourly rainfall depth ranging from 30mm to 150mm estimated from the flood inventory for Berlin collected between 2005 and 2017*



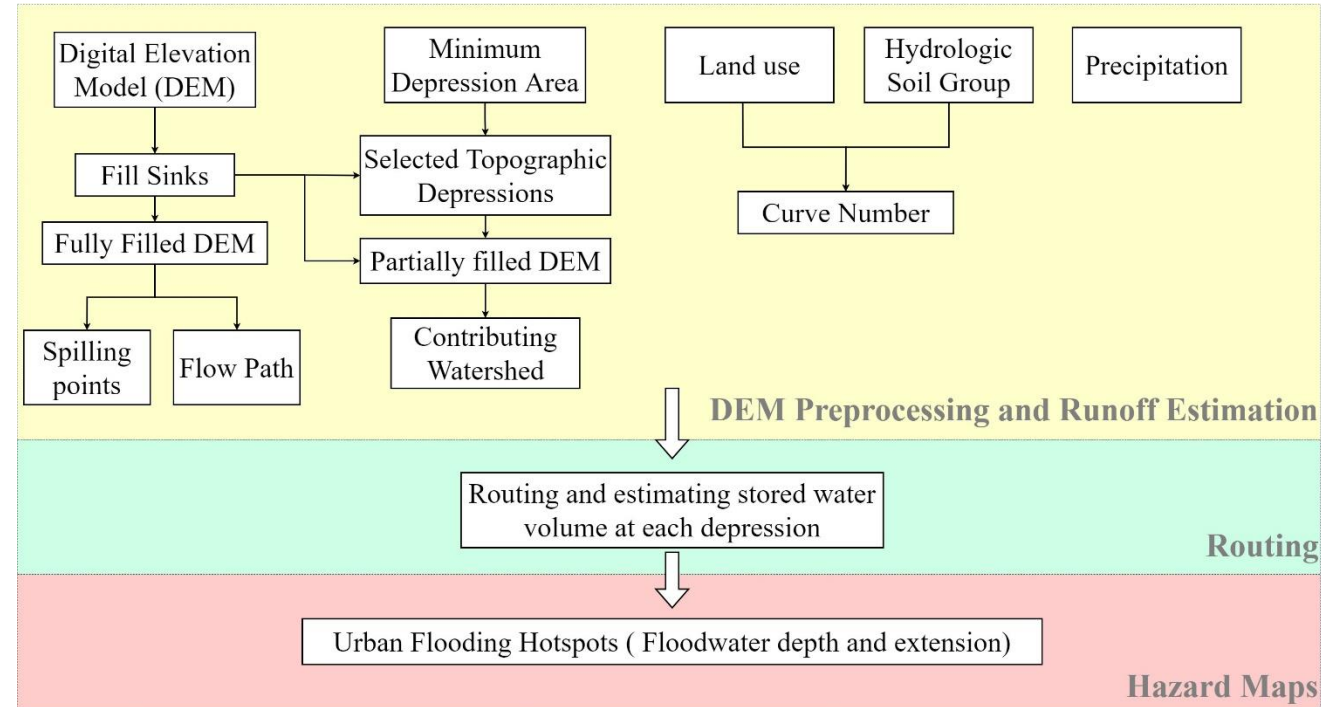
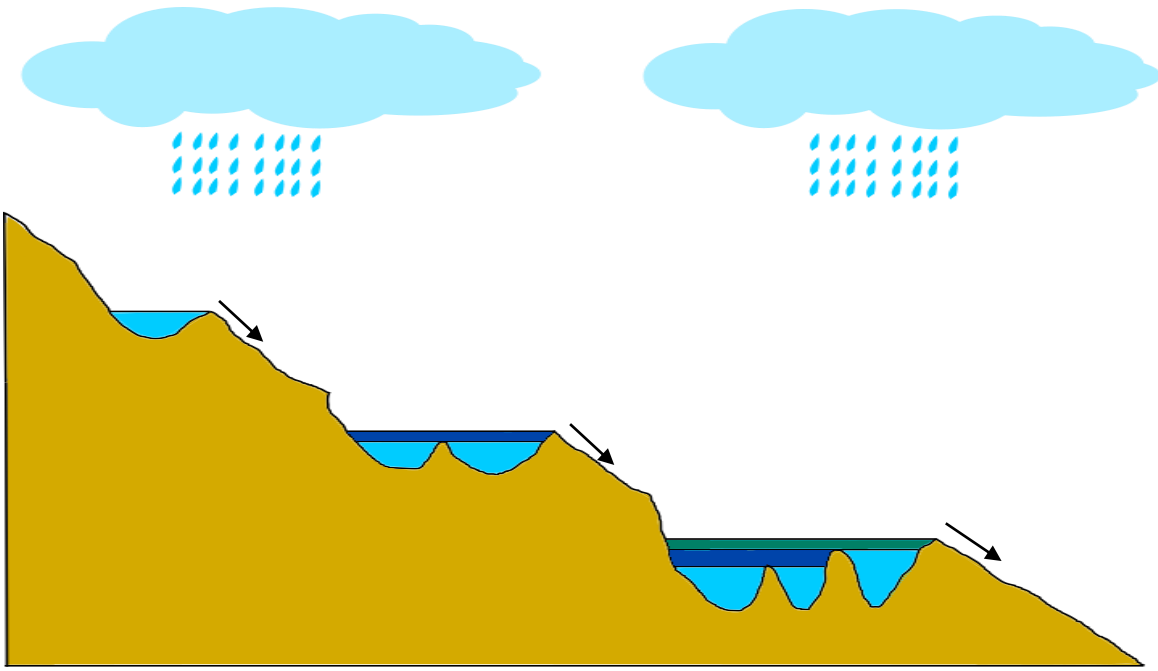
# TELEMAC-2D model

- ❑ TELEMAC-2D model is a free open source 2D Hydrodynamic model.
- ❑ Computations are based on an irregular triangular mesh.
- ❑ Solves the full Shallow Water (Saint Venant) equations in two dimensions.
- ❑ The model supports both finite-volume and finite-element schemes.
- ❑ Rainfall–runoff module is based on the SCS-CN approach.

# Fill-spill-merge (FSM) approach

FSM approach identifies pluvial flood inundation areas based on:

- ❑ Selected depressions (based on depression depth, volume and area)
- ❑ Vertical and Horizontal hierarchy between the depressions
- ❑ Accumulated precipitation volume in depressions



# Topographic wetness index (TWI) approach

- ❑ The TWI was initially introduced by (Kirkby 1975):

$$TWI = \ln\left(\frac{a}{\tan\beta}\right) \quad (1)$$

- ❑ TWI approach:

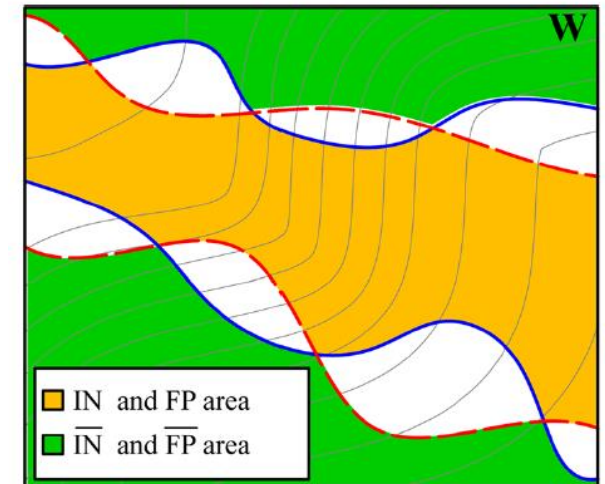
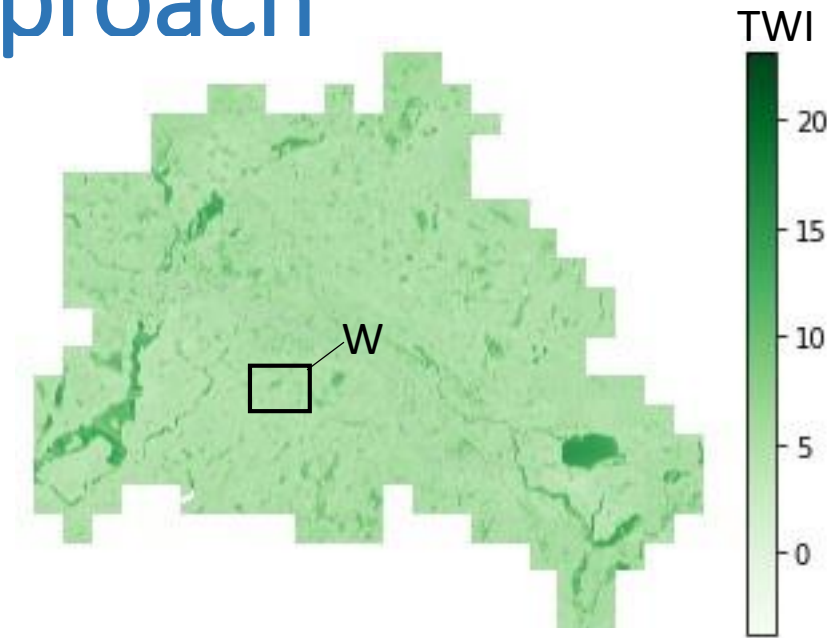
- ✓ Aims to identify a TWI threshold ( $\tau$ ) above which an area is considered as flood-prone.
- ✓ TWI threshold ( $\tau$ ) is estimated based on the maximum likelihood analysis of TWI map and flood plain.

$$L(\tau|W) = P(FP, IN|\tau, W) + P(\overline{IN}, \overline{FP}|\tau, W) \quad (2)$$

Where:

$P(FP, IN|\tau, W)$  is the probability that a point is flooded by TWI method and inundated by TELEMAC-2D model (**Orange area**)

$P(\overline{IN}, \overline{FP}|\tau, W)$  is the probability that a point is neither flooded by TWI method nor inundated by TELEMAC-2D model (**Green area**)



(Jalayer et al., 2014)

# Analysis

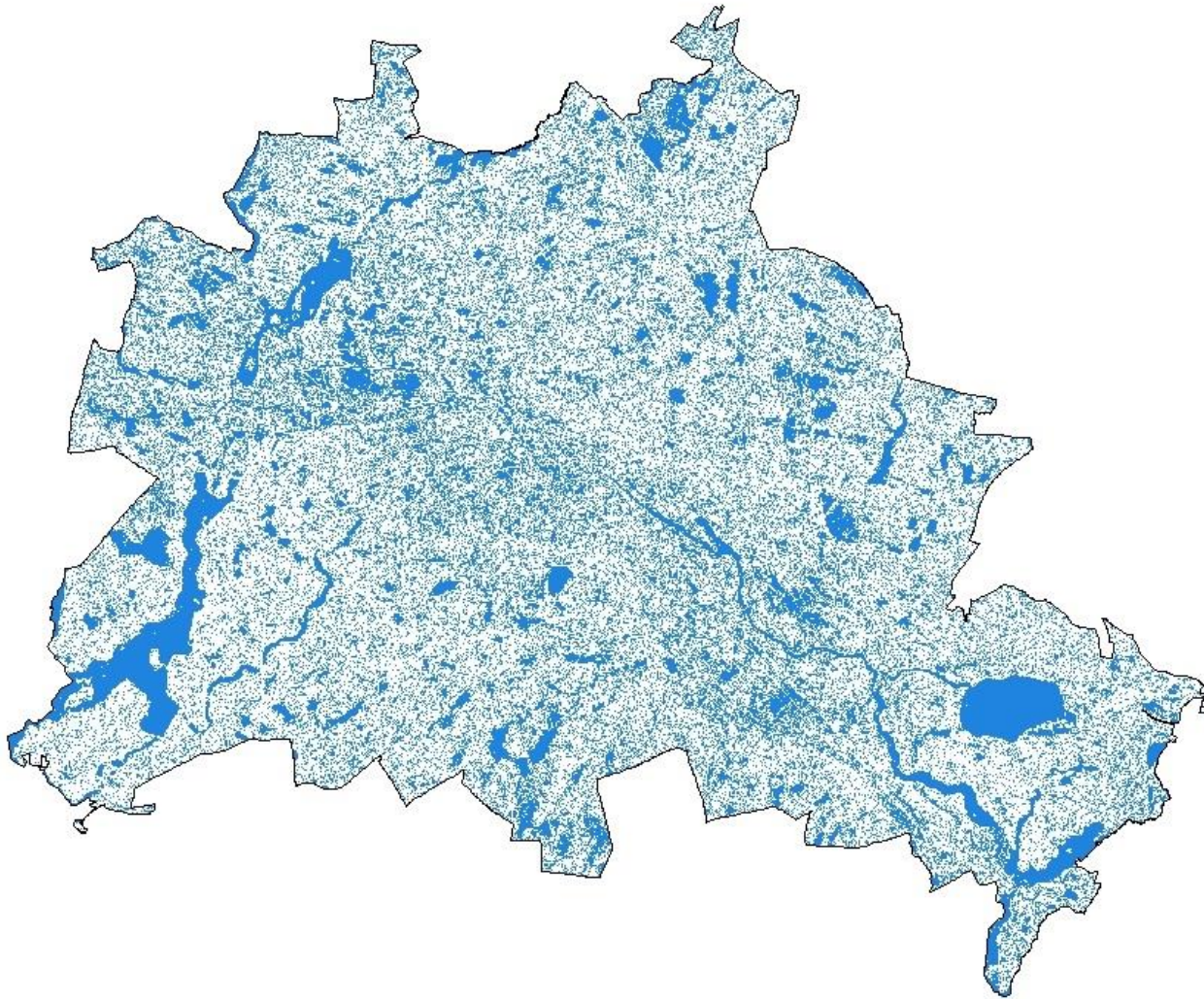
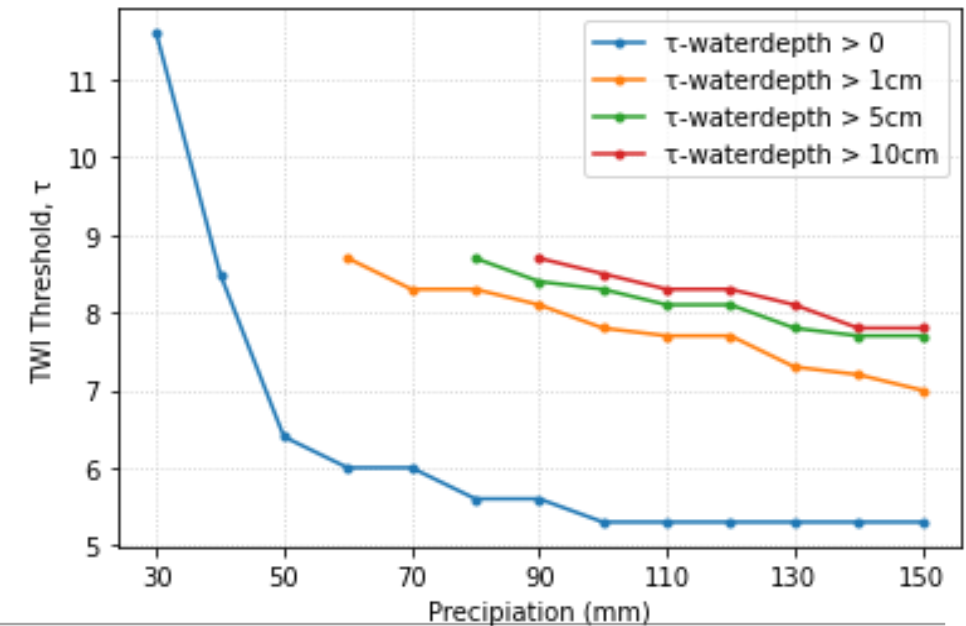
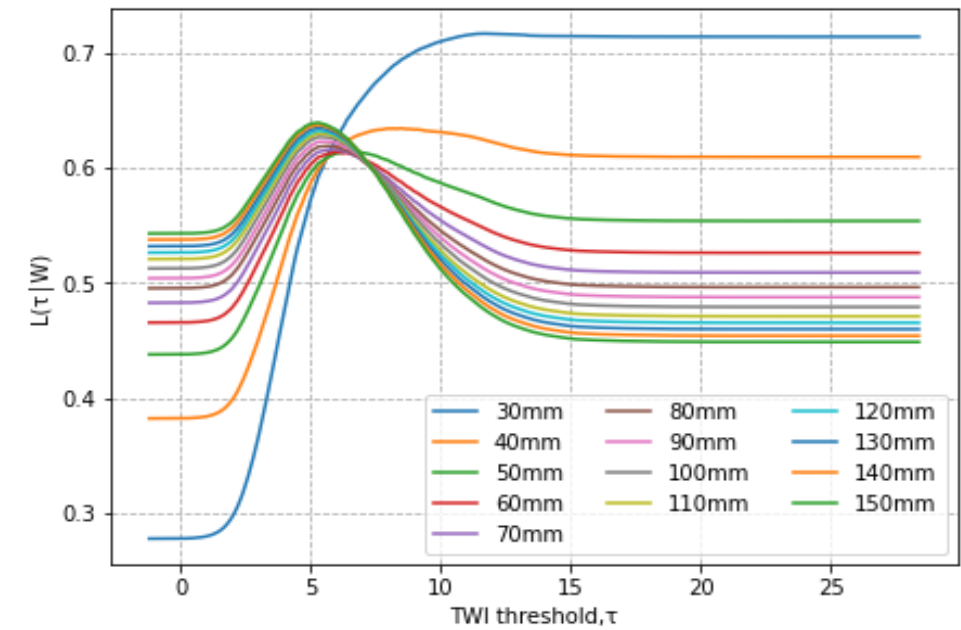
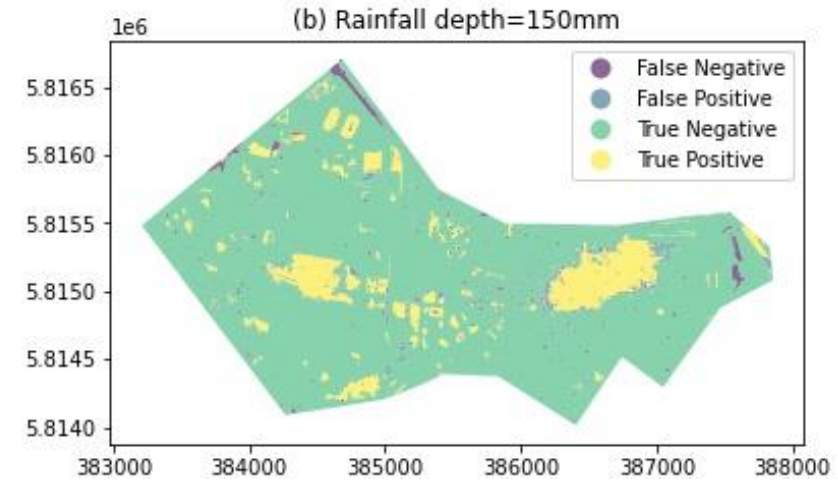
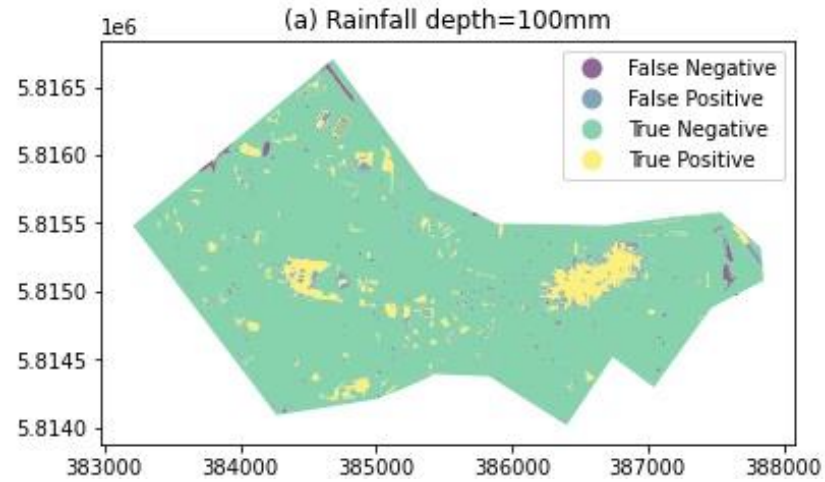


Fig. Flood risk areas in Berlin based on TWI approach  
(Precipitation depth = 50mm)

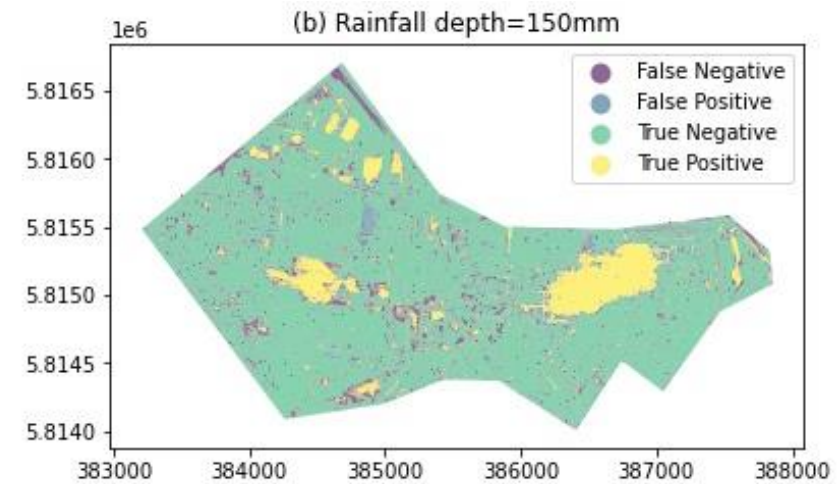
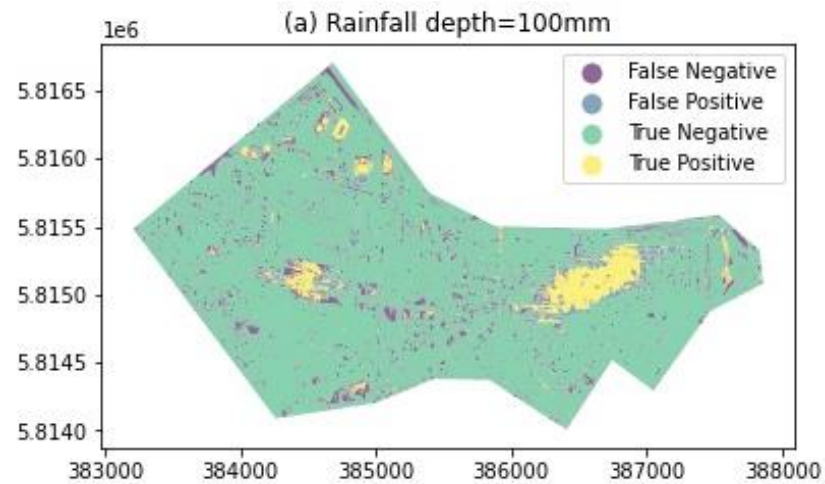


# Analysis

## FSM Method



## TWI Method



# Analysis

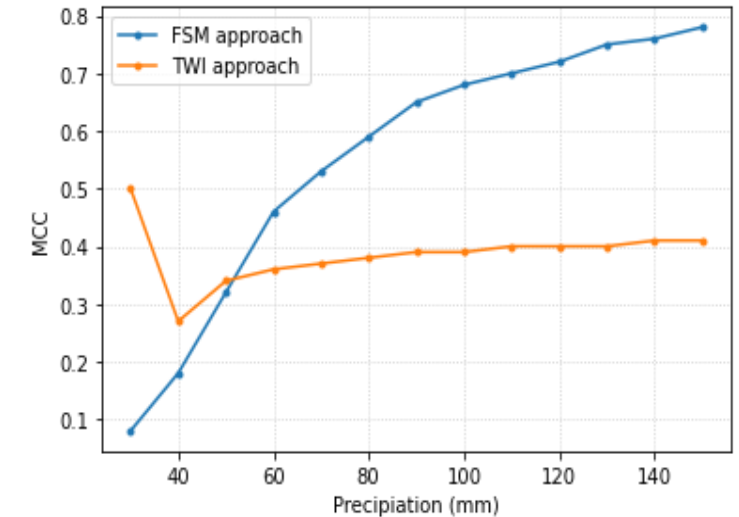
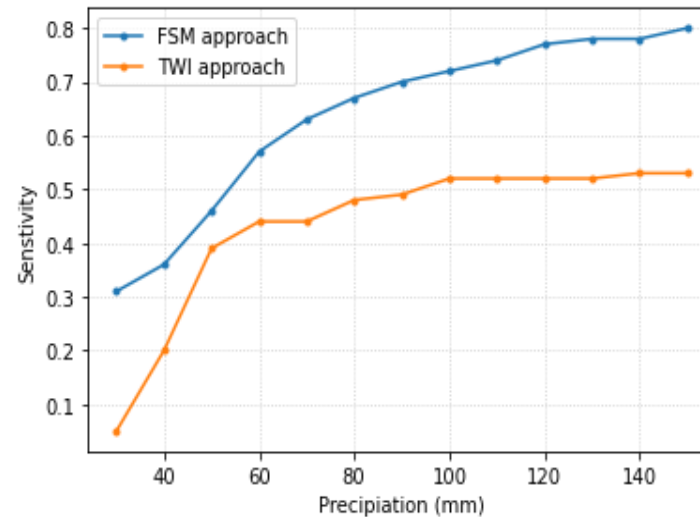
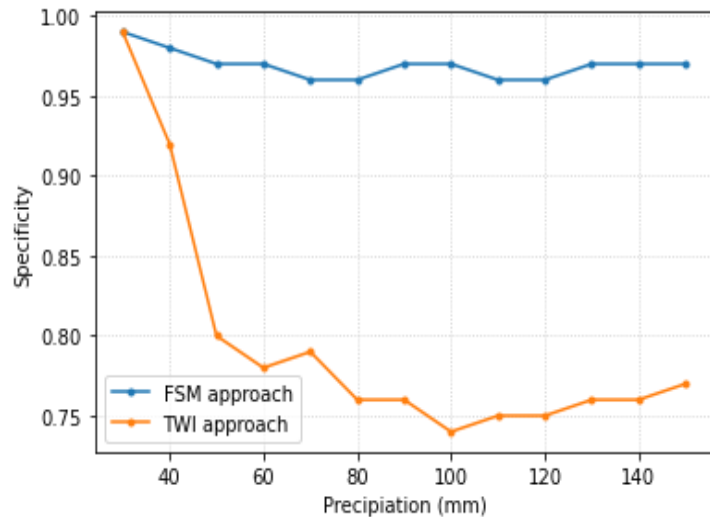
$$\text{Sensitivity (TPR)} = \frac{TP}{TP + FN} \quad (3)$$

$$\text{Specifity (TNR)} = \frac{TN}{TN + FP} \quad (4)$$

$$\begin{aligned} &\text{Matthews correlation coefficient} \\ &= \frac{TP \times TN - FP \times FN}{\sqrt{(TP + FP)(TP + FN)(TN + FP)(TN + FN)}} \quad (5) \end{aligned}$$

Where:

- TP: True positive
- TN: True Negative
- FP: False positive
- FN: False negative



# Conclusions

- ❑ FSM approach is a fast tool for estimating flood plain in urban areas comparing to the 2D hydrodynamic models. However, it requires time to set up the model.
  - ✓ FSM approach performance improves with increasing the precipitation depth.
- ❑ FSM approach has a better performance than the TWI approach.
- ❑ TWI approach can specify the pluvial flood risk areas in the whole city but it has the following limitations:
  - ✓ TWI approach failed to estimate TWI threshold ( $\tau$ ) for low precipitations ( $< 40$  cm).
  - ✓ The estimation of the TWI threshold ( $\tau$ ) is influenced by the definition of inundated areas. The approach defined the inundated area based on water depth (water depth  $> 0$ ). Based on this definition, the pluvial flood plain is not increasing with increasing the precipitation depth, only the flood water depth increase which influenced the estimated TWI threshold ( $\tau$ ).