Integrated Urban Hydrology Modeling Coupled with Satellite Imagery for Flooding and Subsidence Predictions

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Sea-level rise (SLR) and intense precipitation pose significant threats to livability in urban areas along coasts and river estuaries (EEA, 2024). In combination with shallow aquifers and aging sewer systems, SLR and intense precipitation exacerbate the vulnerability of urban centers to small-magnitude but more frequent flooding events.

The negative consequences of these events are not limited to land inundations but extend to the subsurface weakening the soil, triggering subsidence, and resulting in infrastructure failures, road collapses, sinkholes, and utility ruptures.

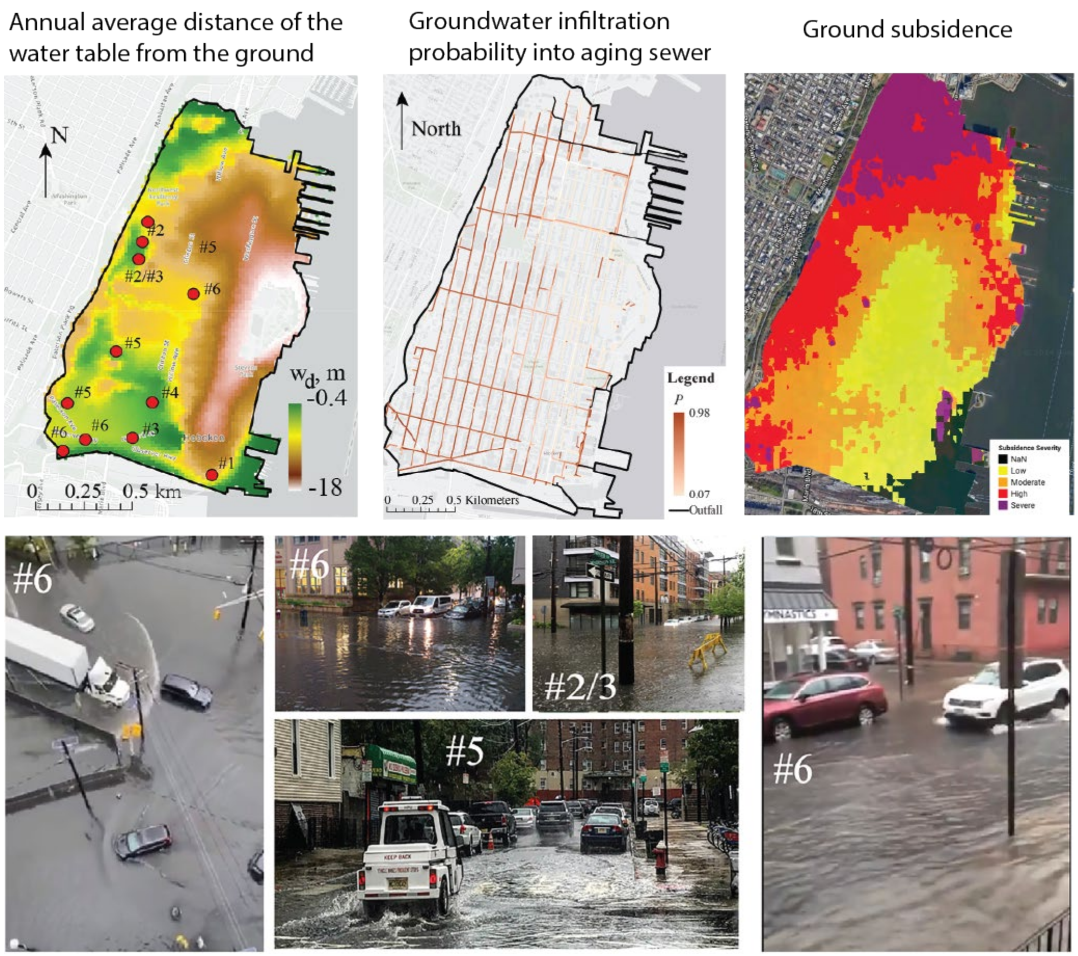

Figure 1. Earlier work results on hydrology and subsidence in Hoboken (NJ, USA) [3,4,5].

Flooding and subsidence in coastal urban areas are, therefore, intertwined phenomena. Despite this notable relationship, there are no tools to identify where in urban areas they may hit infrastructures significantly and threaten public safety. A tool that may predict vulnerability and help to plan preventive intervention is therefore envisaged.

The overarching goal of the proposed project is to design and develop an open-source tool that can help identify sites vulnerable to flooding and subsidence. Moreover, the project aims to evaluate possible strategies that can avert or mitigate the hazards in those identified areas.
We will develop an urban hydro-mechanical model that combines a recent model (named coMS) developed by PI Prigiobbe, which couples MODFLOW and SWMM using Python, with a model to predict subsidence in urban areas developed by PI Sousa. The coupled tool will be calibrated by InSAR and optical imagery to evaluate the effectiveness of the framework through close collaboration with the communities impacted by flooding.

The initial case study will focus on Hoboken, NJ, a flood-prone urban area characterized by shallow groundwater levels, aging sewer systems, and dense infrastructure. The PIs have previously developed groundwater, sewer, and soil models for the region, providing a robust foundation for testing the proposed framework. Hoboken will provide a real-world context for community-focused disaster response.

In the three-year research period, the specific objectives to be addressed include:
1) **Enhancing the coMS Model:** Extend the code coMS to account for subsidence in coastal urban areas using Python programming language to create a novel hydro-mechanical model for urban areas.
2) **Processing and Integrating Remote Sensing Data:** Using and processing multi-temporal InSAR datasets to detect subsidence patterns and validate model outputs.
3) **Scaling**: Apply the model to additional sites in Italy and the United States to assess transferability and refine predictions under different urban settings.

Expected Impact:
This research will result in a decision-support framework that provides early warning capabilities for flooding and subsidence risks. The open-source tool will allow stakeholders to:

1. Pinpoint high-risk zones for targeted infrastructure reinforcements.
2. Improve flood management strategies by integrating hydrological and subsidence forecasting.
3. Support long-term urban resilience planning, especially in coastal and flood-prone environments.

Cross-fertilizing the expertise from three PIs across the geosciences and civil engineering and leveraging the comprehensive knowledge and data availability for the urban site of Hoboken, the proposed project aims at designing and developing a framework to assist experts in the identification of areas vulnerable to flooding and subsidence and guide decision-makers toward possible intervention.

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References

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