**Milwaukee Urban Development**

*Assessing the Drivers of Urban Flood Vulnerability in Milwaukee using the Integrated Valuation of Ecosystem Services and Tradeoffs Urban Flood Risk Mitigation Model (InVEST)*

**Project Team**

***Project Team:***

Madeleine Tango (Project Lead)

Jack Acomb

Annika Harrington

Lisa Sun

Remi Work (Assistant Fellow)

***Advisors & Mentors:***

Lauren Childs-Gleason (NASA Langley Research Center)

Dr. Kenton Ross (NASA Langley Research Center)

***Team Contact:*** Madeleine Tango, madeleine.sophie.tango@gmail.com

***Partner Contacts:***

John Valinch, john@groundworkusa.org

Lawrence Hoffman, lawrence@groundworkmke.org

**Project Overview**

***Project Synopsis:***

This project calculated runoff retention, nominal flood depth and economic damage to buildings in Milwaukee, Wisconsin, using Earth observations and the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Flood Risk Mitigation Model. We assessed the relationship between flood impact and redlining, racial demographics, parks and green spaces, and community resilience estimates. The analysis supports Groundwork Milwaukee/USA in the assessment of flood vulnerability, development of intervention projects, and quantification of unequally distributed flood damages.

***Abstract:***

Milwaukee County has experienced an increase in flooding due to climate change and urbanization. The frequency and severity of flooding vary spatially due to differences in land cover, surface permeability, and infrastructure. Marginalized communities tend to experience disproportionately high flooding and damage due to infrastructural inequalities and limited access to resources. To quantify these differences, we used the Natural Capital Project’s Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Flood Risk Mitigation Model to calculate and create maps of runoff retention, nominal flood depth, and economic damage to buildings in Milwaukee. Our model inputs included land cover, surface permeability, and rainfall. To inform our precipitation inputs, we used NASA’s Integrated Multi-satellite Retrievals for Global Precipitation Measurement (GPM IMERG) and National Weather Service (NWS) data. We assessed the relationship between flood risk and social and environmental spatial data including redlining, racial demographics, greenspace, and community resilience. The data demonstrate that flood risk is higher in historically redlined neighborhoods, majority Hispanic and Black census block groups, areas that lack parks and trees, and areas of low community resilience as measured by the Census Bureau’s Community Resilience Estimates (CRE). These findings will support our partners, Groundwork Milwaukee and Groundwork USA, in their efforts to promote the equitable distribution of resources and support environmental health in urban spaces. The end products of this project provide our partners with tools to assess urban flooding vulnerability, guide future intervention projects, quantify the effects of environmental injustice, and improve stakeholder access to data.

***Key Terms:***

environmental justice, flood risk, vulnerability, InVEST, runoff retention, ecosystem services, Climate Safe Neighborhoods

***National Application Area Addressed:*** Urban Development

***Study Location:*** Milwaukee, Wisconsin

***Study Period:*** January 2010–December 2020

***Community Concerns:***

* In recent years, Milwaukee has suffered from a series of floods, which have worsened in both intensity and frequency due to climate change and urbanization. These floods destroyed houses and infrastructure, impeded transportation, claimed lives, caused sewer overflows, and cost millions of dollars in damages and clean-up.
* Milwaukee is one of the most segregated cities in the United States. Research shows that non-white, historically redlined communities tend to suffer disproportionately from flooding, partially due to unequal distribution of green spaces and impervious surfaces, linking flood damage to systemic racism.

***Project Objectives:***

* Quantify spatial distribution of pluvial flood vulnerability based on runoff retention, nominal flood depth, and estimated economic damage using the InVEST Urban Flood Risk Mitigation Model
* Analyze the relationship between flood risk and historic redlining, racial demographics, green spaces, and community resilience estimates
* Produce maps for partner-community engagement and advocacy
* Contextualize the InVEST Urban Flood Risk Mitigation Model using the Normalized Difference Water Index (NDWI), DEM-derived streams, and the Urban Systems Lab CityCAT model

**Partner Overview**

***Partner Organizations:***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Groundwork USA** | Cate Mingoya, Director of Capacity Building; John Valinch, Manager of Equity and Resilience Programs | End User |
| **Groundwork Milwaukee** | Lawrence Hoffman, Deputy Director of GIS; Jess Haven, Outreach & Organizing Director; Keviea Guiden, Climate Safe Neighborhoods (CSN) Organizing Associate | End User |

***Decision-Making Practices & Policies:***

Groundwork USA is a network of trusts that work with communities across the country to improve their environmental, social, and economic conditions, as well as to improve community members’ health and quality of life. Groundwork Milwaukee is part of Groundwork USA’s network with a focus on transforming brownfields, educating youth and other community members, and protecting urban waters. One of their main goals is to support communities in increasing their flood resiliency by mapping flood risk, constructing green infrastructure, and engaging with policymakers. They previously predicted flood impacts using the CityCAT model, which measured flood risk utilizing topographical data, and now want to complement those outputs by leveraging the InVEST model, which takes into account soil and land cover classification. Groundwork Milwaukee is one of several Groundwork trusts participating in Climate Safe Neighborhoods, a project aimed at studying the relationship between historic redlining and modern-day urban climate impacts. Groundwork uses GIS analyses, including ones provided by DEVELOP and the InVEST model, to show how historically redlined neighborhoods tend to suffer disproportionately from environmental hazards, such as flooding, heat islands, and brownfields. This project demonstrates that environmental injustices are not coincidental, but rather are a result of systemic racism.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **GPM IMERG** | Precipitation | Precipitation data were used to inform rainfall estimations in the InVEST Urban Flood Model. |
| **Landsat 7 ETM+** | NDWI | Images were used to calculate NDWI, which we compared with InVEST nominal flood depth outputs. |

***Ancillary Datasets:***

* USGS National Land Cover Dataset (NLCD) – Land cover and land use data | for input into the InVEST Urban Flood Risk Mitigation Model
* USDA Digital General Soil Map of the United States (STATSGO2) – Soil type and drainage class | for calculating curve numbers for the InVEST Urban Flood Risk Mitigation Model
* Milwaukee County 2020 LiDAR 2D Buildings – Milwaukee County building footprints | for input into the InVEST Urban Flood Risk Mitigation Model
* City of Milwaukee Master Property File – Monetary valuations of built structures | for input into the InVEST Urban Flood Risk Mitigation Model
* Wisconsin DNR Hydrologic Units 10 Digit Watersheds – Watershed boundaries | for input into the InVEST Urban Flood Risk Mitigation Model
* Wisconsin DNR Hydrologic Units 12 Digit Subwatersheds – Subwatershed boundaries | for input into the InVEST Urban Flood Risk Mitigation Model
* Milwaukee Metropolitan Sewerage District (MMSD) City of Milwaukee Basement Backups – Reports of basements flooding in Milwaukee from 2008–2021 | for comparison with locations of risk as determined by InVEST
* 100 Year Baseline Simulation Output from The New School Urban Systems Lab CityCAT Model – A pluvial flood model output| for estimating local flood risks
* US Census Bureau 2020 Census Demographic Data – Population and demographic data by census tract from the most recent US Census | for input in exposure mapping

***Modeling:***

* Natural Capital Project’s InVEST Urban Flood Risk Mitigation Model (Contact: Dr. Kenton Ross, NASA Langley Research Center) – Urban pluvial flood model | for calculating rainfall runoff, runoff retention, and potential economic damages of pluvial flooding

***Software & Scripting:***

* Esri ArcGIS Pro 2.9 – GIS software | for analysis of InVEST flood risk outputs

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Flood Risk Mitigation Map Package** | GPM IMERG  Landsat 7 ETM+ | In our final data package, we will provide map products from the InVEST Urban Flood Risk Mitigation Model (runoff retention, nominal flood depth, and economic damage estimates), as well as maps and analyses of redlining, community resilience estimates, reported race data, green space, impervious surfaces, and basement backup surveys, in relation to the flood risk outputs. These layers will assist partners with identifying areas of high risk and vulnerability and corresponding infrastructure costs of select locations. | N/A |

***Product Benefit to End User:***

The Flood Risk Mitigation map package will inform Groundwork Milwaukee, community members, and policymakers which areas have high runoff values (mm) and low runoff retention rates within Milwaukee County. This package includes the InVEST model outputs showing runoff retention by cubic meter and percent, flood volume (mm), and damage in dollars to built infrastructure, both in raster format and averaged by block group. These data will support Groundwork Milwaukee’s efforts to identify areas that are at high risk of flood damage and to inform policymakers of areas in most need of flood mitigation investment. The maps also explore the relationship between high flood risk and the distribution of greenspace, redlined districts, community resilience, and race. These results highlight environmental injustices and enable Groundwork to engage in conversations with stakeholders and policymakers. The maps also make the research on flooding and environmental justice more publicly accessible to community members and build local capacity to understand the applications of NASA Earth observations.

***Project Continuation Plan:***

We will provide the incoming team with the outputs of the model and our analyses. The incoming team can supplement these results by working with Groundwork on future surveys, forums, and other forms of community engagement. We will also provide the incoming team with all raw input datasets and processed input datasets, and include a detailed methodology on how data were obtained, processed, entered into the model, and analyzed.

**References**

Capps, K., & Cannon, C. (2021, March 15). *Redlined, Now Flooding*. Bloomberg. <https://www.bloomberg.com/graphics/2021-flood-risk-redlining/>

Foltman, L., & Jones, M. (2019, February 28). *How Redlining Continues To Shape Racial Segregation In Milwaukee*. WisCONTEXT. <https://www.wiscontext.org/how-redlining-continues-shape-racial-segregation-milwaukee>

McPhearson, T., Cantis, H. C., Tomateo, C., Cook, E., Kennedy, C., & Grabowski, Z. (n.d.). *Environmental Justice of Urban Flood Risk and Green Infrastructure Solutions*. Urban Systems Lab. <https://urbansystemslab.com/urbanfloodrisk>

The New School Urban Systems Lab. (n.d.). *Environmental Justice of Urban Flood Risk and Green Infrastructure Solutions: methodological considerations and modeling assumptions.* <https://static1.squarespace.com/static/552ec5f5e4b07754ed72c4d2/t/60db1f326d3d82420f558b66/1624973106683/USL+Urban+Flood+Risk-+Methods+and+Assumptions.pdf>