**Milwaukee Urban Development II**

*Assessing Climate Vulnerability through the InVEST Models on Urban Cooling in Milwaukee Using NASA Earth Observations*

**Project Team**

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**Project Overview**

***Project Synopsis:***

The climate crisis poses disproportionate threats of extreme heat and precipitation to marginalized communities in Milwaukee, Wisconsin. The first term of this project assessed flood vulnerability in Milwaukee using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Flood model. The second term applied the InVEST Urban Cooling model and sociodemographic data to evaluate unequal distribution of urban heat, heat mitigation strategies, and vulnerability to urban heat effects. Our analysis and tutorials will provide Groundwork Milwaukee and Groundwork USA tools to perform their own urban heat analyses, identify interventions, and improve data access for community members.

***Abstract:***

Milwaukee’s neighborhoods experience increased social, health, and ecological stress from the Urban Heat Island (UHI) effect due to changing land cover and climate. Extreme urban heat disproportionately affects Black and Latine communities due to systematic disinvestment in infrastructure and lack of resources to cope with heat. Our partner, Groundwork Milwaukee, supports Environmental Justice organizing around urban heat in historically redlined neighborhoods. This study explores heat mitigation in Metcalfe Park, one such neighborhood that is a focus area for our partner, as well as across the city and county of Milwaukee. Our team utilized the Natural Capital Project’s InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs) Model for Urban Cooling to model heat mitigation scenarios for Milwaukee in support of Groundwork’s climate resilience and heat mitigation work. The data inputs used in our analysis were Land Use Land Cover (LULC), evapotranspiration, and surface temperature derived from NASA Earth observations, as well as a biophysical table containing land cover class attributes. We developed a heat vulnerability index from American Community Survey datasets and satellite imagery to identify areas in most need of heat mitigation intervention. We found that central and northwest city areas, home to a majority of Milwaukee’s Black and Latine population, have low heat mitigation and high vulnerability to heat impacts compared to the rest of the county. We also found that tree canopy increases across scales are effective in promoting heat mitigation. Our results and end products will bolster the efforts of our partners to make decisions on heat mitigation strategies, build community resilience, and reverse legacies of environmental racism in the face of extreme heat and climate change.

***Key Terms:***

urban heat island, urban cooling, InVEST, Environmental Justice, Climate Safe Neighborhoods, environmental vulnerability, systemic racism, redlining

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

***Study Location:*** Milwaukee, WI

***Study Period:*** June to September of 2010 – 2021

***Community Concerns:***

* Extreme heat is the leading cause of weather-related fatalities in the US. It disproportionately impacts people with preexisting health conditions, the elderly, and those with limited access to resources, and has adverse effects including heat stress and illness, environmental degradation, and economic strain.
* Many of the hottest urban areas are home to communities of color and those with limited access to resources, and this is very true in Milwaukee, one of the most segregated cities in the US. Heat-related illness, lack of access to cooling centers, and high energy costs during summer months put many of these marginalized communities at risk.
* Milwaukee’s climate resilience studies and efforts tend to focus more on flooding vulnerability rather than heat. However, heat is an increasing risk to historically redlined communities in the city as climate change and urban development intensify the Urban Heat Island (UHI) effect.

***Project Objectives:***

* Map the heat mitigation capacity of Milwaukee neighborhoods using the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Cooling model to provide partners with a better understanding of community resilience
* Quantify the spatial distribution of urban heat vulnerability throughout Milwaukee using Earth observations in combination with sociodemographic data.
* Create tutorials on InVEST model methodologies to build partner capacity to effectively use end products and pursue their own analyses moving forward
* Produce an informational flyer to educate community members on the effects of climate change, including flood risk and the UHI effect, as well as climate mitigation strategies underway in Milwaukee

***Previous Term:***

Summer 2022 (VEJ) – Milwaukee Urban Development

**Partner Overview**

***Partner Organization(s):***

|  |  |  |
| --- | --- | --- |
| **Organization** | **Contact (Name, Position/Title)** | **Partner Type** |
| **Groundwork Milwaukee** | Lawrence Hoffman, Deputy Director of GIS | End User |
| **Groundwork USA** | John Valinch, Manager of Equity and Resilience Programs | End User |

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

Groundwork USA is a national network of local trusts across the country, including in Milwaukee, which partners with communities, local governments, and businesses on Environmental Justice efforts. Groundwork Milwaukee specifically focuses on brownfield remediation, urban gardens, water resource stewardship, green infrastructure, and community and youth education. Their work centers residents’ perspectives and helps communities organize around Environmental Justice, influence city-wide decision-making, and build partnerships to address environmental issues. Groundwork Milwaukee is participating in the Climate Safe Neighborhoods program, through which they study the connection between redlining and impacts of climate change on marginalized communities in the city, specifically in the Metcalfe Park neighborhood. As part of this program, they have worked with environmental spatial data to quantify disproportionate impacts of flooding and heat. Additionally, they collaborated with DEVELOP’s Milwaukee Urban Development I team to study flood risk through the InVEST flood model. Through these analyses, Groundwork explores the ways in which the historical redlining of marginalized communities contributes to disproportionate climate impacts in the present. The organization and their partners use this information to provide concrete evidence for policymakers on environmental injustice and inform green infrastructure interventions in the community.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Landsat 8 OLI** | Surface reflectance | Surface reflectance data spanning 2013 to 2021 were used in concert with USGS National Land Cover Dataset (NLCD) as an input for the InVEST Urban Cooling Model. |
| **Landsat 8 TIRS** | Land surface temperature | Land surface temperature data spanning 2013 to 2021, provided surface temperature inputs to the InVEST Urban Cooling Model. |
| **ISS ECOSTRESS** | Evapotranspiration | Evapotranspiration and night time surface temperature data were acquired and used as inputs for the InVEST Urban Cooling Model. |

***Ancillary Datasets:***

* USGS National Land Cover Dataset (NLCD) Land Cover Layer – Land cover class data for input into the InVEST Urban Cooling Model
* Wisconsin Department of Natural Resources Community Canopy Cover Layer – Tree cover data for input into the InVEST Urban Cooling Model ‘s biophysical table
* US Census Bureau American Community Survey (ACS) Data, 2020 5-Year Survey – Sociodemographic datasets for use in constructing the heat vulnerability index
* HOLC Neighborhood Redlining Grades – Boundaries of historically redlined areas for analysis of connections between UHIs and redlining
* Milwaukee County GIS and Land Information Office Milwaukee County Parks and Municipal and State Parks Layer – Park locations and boundaries within Milwaukee County for mitigation scenario inputs into the InVEST Urban Cooling Model
* Milwaukee County GIS and Land Information Office Parcels with Property Information Layer – Vacant lot boundaries within Milwaukee County for mitigation scenario inputs into the InVEST Urban Cooling Model
* Milwaukee County GIS and Land Information Office Buildings Layer – Building footprints for building intensity inputs into the InVEST Urban Cooling Model
* Milwaukee County GIS and Land Information Office LIDAR Digital Surface Model – Height above ground to calculate building intensity inputs into the InVEST Urban Cooling Model

***Modeling:***

* Natural Capital Project’s InVEST Urban Cooling Model (Contact: Dr. Kenton Ross, NASA Langley Research Center) – Urban cooling model for calculating UHI effect mitigation scenarios

***Software & Scripting:***

* Google Earth Engine – for downloading and preprocessing InVEST input data
* Esri ArcGIS Pro 2.9 – for construction of InVEST cooling model raster inputs and analysis of model outputs
* R v4.04 – for importing sociodemographic datasets, running principal component analysis, and constructing heat vulnerability index

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **Urban Heat Mitigation Map Package** | Landsat 8 OLI  Landsat 8 TIRS  ISS ECOSTRESS | This map package will include InVEST results including cooling capacity, heat mitigation index, and modeled temperature values, as well as satellite datasets that we used as model inputs. It will also incorporate as well as map layers and plots relating our results to redlining and Environmental Justice. Partners will use this package to identify areas of high risk and vulnerability in order to better direct mitigation efforts. | N/A |
| **Heat Vulnerability Index Package** | Landsat 8 OLI  Landsat 8 TIRS  ISS ECOSTRESS | This map package will include results from our heat vulnerability index and the principal component analysis we used to create it. |  |
| **InVEST Flood and Cooling Tutorial/ Project Methodology** | N/A | This tutorial will help Groundwork interpret and use heat mitigation map and vulnerability index results to inform decision-making, and it will build their staff’s capacity to carry out further analyses in the future. | N/A |
| **Milwaukee Climate Resiliency Flyer** | N/A | This flyer will explain background information, findings on UHIs, and mitigation strategies in a concise, engaging, and accessible format to enhance climate change communication for Milwaukee residents. This will help Groundwork communicate the risks of UHIs and the benefits of mitigation strategies to community members and other collaborators. | N/A |

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

The Urban Heat Mitigation map package will demonstrate urban heat distribution across Milwaukee County, convey the factors contributing to this phenomenon, and facilitate communication for the potential of various mitigation scenarios to address the issue. The Heat Vulnerability Index package will help partners identify areas of high heat impacts and vulnerability, contributing more detail to their previous index and building their capacity for future analyses of sociodemographic data. The InVEST Flood and Cooling Tutorial will serve as a guide for Groundwork Milwaukee on the use of both models to evaluate mitigation efforts and conduct their own geospatial analyses using NASA Earth observations. The Milwaukee Climate Resiliency Flyer is a communication tool to convey flood and heat island risk and bolsters the importance of support for future mitigation strategies, aiding the development of Groundwork Milwaukee's outreach to the general public and local community organizations. These products will build Groundwork Milwaukee’s capacity to apply the results from this project to heat mitigation decision-making, conduct their own analyses in the future, help educate residents on heat and flooding risks in their communities, and support advocacy for mitigation interventions.

**References**

Foltman, L. & Jones, M. (2019, February 19). *How redlining continues to shape racial segregation in Milwaukee.* Wisc. <https://apl.wisc.edu/shared/tad/redlining-milwaukee>

Haven, L. H., Mingoya, C., Valinch, J., & Haven, J. (2022, May 12). *Climate Safe Neighborhoods*. ArcGIS StoryMaps. <https://storymaps.arcgis.com/stories/25e047d8917744c8acfb72ec65b845de>

Hoffman, J. S., Shandas, V., & Pendleton, N. (2020). The effects of historical housing policies on resident exposure to intra-urban heat: a study of 108 US urban areas. Climate, 8(1), 12. <https://www.mdpi.com/2225-1154/8/1/12/htm>