**InVEST Urban Development**

*Incorporating Earth Observation Data into the Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Flood Risk Mitigation Model Python API*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

The Natural Capital Project’s Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Flood Risk Mitigation (UFRM) model, which benefits from its simplicity and robustness, is commonly used in NASA DEVELOP projects for urban planning and environmental justice. The InVEST model gives insight into where floods have and will occur in different regions, allowing for improved resilience in communities. This project modifies the model to incorporate precipitation rasters, including GPM IMERG, into the flood runoff/retention calculation instead of a singular rainfall depth value across the study area.

***Abstract:***

Urban flooding poses as one of the biggest issues for cities today as its impacts are amplified by both climate change and urbanization. The Natural Capital Project’s Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Flood Risk Mitigation (UFRM) model, which benefits from its simplicity and robustness, is commonly used in NASA DEVELOP projects for disaster mitigation, urban planning, and environmental justice issues. While InVEST UFRM model was able to produce the surface water runoff and retention map sufficient for the scopes of past projects, the model accuracy and spatial variability need improvement. Since the current InVEST UFRM model employs constant rainfall depth for all pixels in the area of interest (AOI), the model suffers from inaccurately estimating rainfall depth, runoff volume, and flood depth. Therefore, we adapted the model so that satellite-based precipitation raster datasets (i.e., Integrated Multi-satellitE Retrievals for Global Precipitation Measurement [GPM IMERG]) can be used instead of a single constant value. We simulated the flood events on August 21st and August 22nd, 2017, in Wyandotte County, Kansas Cityusing both our modified and the original InVEST UFRM model and then compared the results after incorporating rainfall raster into the model. Areas with developed land on the land use map predicted moderate to high flood volume in the original volume regardless of the actual amount of precipitation. The modified model considered the rainfall depth’s spatial variation achieving less overestimation of flood runoff and volume at low-to-moderate rainfall area.

***Key Terms:***

Urban flooding, flood damage assessment, remote sensing, flood modeling, hydrological extremes, natural hazards

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

***Study Location:*** Wyandotte County, KA

***Study Period:*** August 2017

***Community Concerns:***

* Urban floods frequently have a significant impact on people, infrastructure, and the environment.
* The rapid urbanization and the increasing frequency of extreme weather events have made urban areas more vulnerable to floods.
* Urban floods can lead to property damage, loss of life, and displacement of people.
* The floodwater can also contaminate water sources, leading to the spread of waterborne diseases.

***Project Objectives:***

* Integrate Earth observation data into the InVEST UFRM model
* Enhance the model’s current capabilities
* Illustrate the benefits of incorporating rainfall rasters in the model
* Test the sensitivity of the model
* Compare the original and improved model
* Validate the improved model
* Prepare the documentation to assist future users

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameter** | **Use** |
| **Sentinel-1 SAR** | Vertical transmit/vertical receive (VV) backscatter intensity | Sentinel-1 VV SAR intensity images were used to derive a flood extent map to cross-compared with the InVEST UFRM model flood result. |
| **GPM IMERG** | Precipitation | GPM IMERG precipitation rasters were used as input into the modified InVEST model. Total daily precipitation rasters were used to simulate flood runoff/retention of a storm event in 24 hours. |

***Ancillary Datasets:***

* United States Department of Agriculture (USDA) Gridded Soil Survey Geographic (gSSURGO) Database, 2019 – soil type and drainage class for calculating curve numbers for the InVEST UFRM model
* United States Geological Survey (USGS) National Land Cover Database (NLCD), 2019 – land cover and land use data for input into the InVEST UFRM model
* USGS NHDPlus (National Hydrography Dataset Plus) High Resolution (HR), 2018 – regional watershed boundary dataset containing HUC 8 and 12 watersheds for creating a delineated watershed polygon

***Modeling:***

* Natural Capital Project Integrated Valuation of Ecosystem Services and Tradeoffs (InVEST) Urban Flood Risk Mitigation (UFRM) Model (Dr. Kenton Ross, NASA Langley Research Center)

***Software & Scripting:***

* ArcGIS Pro Version 3.1.0 – Data visualization, Cartography
* Python 3.10 – Raster processing, InVEST UFRM model
* Google Earth Engine – Data acquisition, Satellite-based flood extent mapping

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used** | **Partner Benefit & Use** | **Software Release Category** |
| **InVEST Flood Analysis** | GPM IMERG | A modified InVEST model for flood analysis will benefit future DEVELOP teams and potential end user organizations in generating more accurate flood surface runoff and retention maps for mitigation. |  |
| **InVEST Tutorial** | GPM IMERG | A detailed tutorial on the modified InVEST model will help future teams incorporate this workflow into their flood analysis for their respective city of interest and apply this work to end user organizations. |  |

**References**

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**Project Reflections**

**Does the team consider this project to be successful?**

The team considers this project to be a large success. The goal of the project was to be able to implement raster data for the precipitation input in the model and we accomplished that. In addition, we performed some validation and sensitivity analysis on the model and precipitation input. GPM IMERG improved the model estimation or urban flooding, but we both agree that further downscaling and/or an improved spatial resolution on the precipitation input would improve the success of this model.

**If you had the opportunity to do this project again, what would you do differently?**

Some of the challenges and concerns we occurred throughout this term are out of everyone's control, but there are still things we would change. We would try to have more than two team members on the team, have an improved project outline in the beginning, and have a workspace for the members of the team. Although these aren't specific things that we would do differently, they would definitely improve the flow and outcomes of the term. Also, identifying the dates we want to use the model on before running it would have saved a lot of time as it seemed the floods in KC didn’t have all available data needed for analysis and validation.

**Is this project planned to continue into another term? If so, please reflect on why you think it should or should not.**

No. This project is not supposed to be continued, but a separate project building off of this term will take place in the subsequent term. We agree that this project should be continued. There is a lot of opportunity for further validation both more in depth and quantitative. Additionally, downscaling efforts for further improvement of the accuracy of the precipitation over a higher spatial resolution. The data for this project is easily accessible for all over the US and the model is easy to use. The outputs are also very important for different communities, especially in urban planning realms. We were able to successfully complete this project with two participants and believe that more work on this model will further improve it.

**Do you have any recommendations for future teams pursuing a similar project to consider?**

One tip is to identify the storm events or the dates you want to run the model for before you begin running the model. It is important to ensure that you have adequate data for the days (and potential validation data for the days) you want to run the model for. It is also important to research the flood events and extents of the flood before to determine the appropriate study area.

**Earth Observation Data**

*GPM IMERG (*[*https://gpm.nasa.gov/data/imerg)*](https://gpm.nasa.gov/data/imerg))

1. **Source**: Downloaded from NASA Earth Explorer on the GPM IMERG website (<https://disc.gsfc.nasa.gov/datasets/GPM_3IMERGDF_06/summary)>
2. **General Overview**: The data is very easy to download and there was lots of information for support (in our tutorial, we go into detail about how to download this data)
3. **Acquisition**: Getting the data from Earth Explorer was easy
4. **Processing/Analysis**: We had no issues processing/analyzing the data

*Sentinel-1 SAR* (<https://developers.google.com/earth-engine/datasets/catalog/COPERNICUS_S1_GRD> )

1. **Source**: From Google Earth Engine
2. **General Overview**: The product was easy to acquire. Rasters are exported to Google Drive and then downloaded. Google Earth Engine has a user interface map and did some pre-processing steps to the Sentinel-1 SAR image
3. **Acquisition**: No problem
4. **Processing/Analysis**: Flood map derivation from Sentinel-1 for urban area was challenging with flat terrains being misclassified as water. We had to switch to a change detection water classification method.

**Culminating Research Questions Generated**

**Team-Identified Future Work:**

1. Future work in validation and downscaling of the precipitation raster would be beneficial to the improvement of the model. It was unfortunate that there is no satellite-based coincident image with significant flood event in Kansas City. Using a different study area with established in-situ data will also allow for more predictions to be made and new validation efforts to be tested.
2. Moving forward, some improvements that can be made on this model are to downscale GPM in order to increase the spatial variability of the input precipitation raster. Also, improving the curve number calculations would provide more accurate retention rates. With any project, further validation improves the accuracy and dependability of models. Lastly, application in other locations, such as Richmond Virginia and Sacramento California will allow more individuals to work with this model, improve it, and utilize the results.