**Fairfax Water Resources**

*Estimating Urban Flood Susceptibility, Historical Flooding Extent, and Land Cover Change in Fairfax County, Virginia to Aid in Flood Mitigation Planning*

**Project Team**

***Project Team:***

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**Project Overview**

***Project Synopsis:***

Fairfax County, Virginia has experienced frequent localized storms and floods over the past 20 years. These events are likely caused by increased frequency and severity of extreme weather, as well as increased urbanization in Fairfax County. In July of 2019, a single flash flood event generated over $14 million worth of damages to county property, residences, and buildings. This project created maps that demonstrate impervious surface and urban tree canopy change, flood susceptibility, and past local inundation events. The Fairfax County Department of Public Works and Environmental Services can use these maps to further inform their flood mitigation decision making.

***Abstract:***

Between 2000 and 2020, Fairfax County, Virginia experienced extreme weather events that caused severe flooding and degradation of roads, businesses, and other public property. A single flood event on July 8th, 2019 resulted in $14.8 million in damages. These flood events routinely impact the community, often resulting in power outages, school closures, and downed trees. The Fairfax County Department of Public Works and Environmental Services partnered with DEVELOP to explore how remotely sensed data could be integrated to support its current flood mitigation efforts. This project used environmental factors such as elevation, slope, and topographic wetness index from Earth observation derived data to map flood susceptibility. We utilized Landsat 7 Enhanced Thematic Mapper Plus (ETM+), Landsat 8 Operational Land Imager (OLI), Sentinel-1 C-Band Synthetic Aperture Radar (C-SAR), and Sentinel-2 Multispectral Instrument (MSI) to map historic flooding events in Fairfax County. These maps will support flood management practices for the Fairfax County Department of Public Works and Environmental Services through the integration of remotely sensed data. Our results show that developed areas in the county are more susceptible to flooding, coinciding with analysis of flood factors, which indicated that imperviousness and tree canopy were the most influential drivers in flood susceptibility. Other results show that using Earth observations to map historical flooding is limited in urban areas due to false positives from SAR imagery between water and shadows. Further research is necessary to evolve the historical flood mapping technique if Earth observations are to be incorporated in future historical flood analysis.

***Key Terms:***

Remote sensing, historic flood mapping, Landsat 8 OLI, random forest classification

***National Application Areas Addressed:*** Water Resources, Disasters, Urban Development

***Study Location:*** Fairfax County, VA

***Study Period:*** January 2000 to December 2020

***Community Concerns:***

* Over the last 20 years, Fairfax County has experienced increasingly extreme weather events such as tropical storms and hurricanes attributed to global climate change.
* In 2019, the county experienced a rainfall event that severely impacted county property, residences, and businesses, costing the county a total of $14.8 million in damages.
* County flood management is currently limited to a reactive approach based on citizen reported flood complaints which may not always indicate where flooding occurs due to disparities in reporting rates by residents across the county.
* A detailed understanding of flood risk in the county is needed to adopt a proactive approach for flood management.

***Project Objectives:***

* Identify areas where flood mitigation measures may be beneficial or where aid may be needed during future flood events through a static flood susceptibility map of Fairfax County
* Demonstrate how urban tree canopy and impermeable surfaces in Fairfax County have changed since 2000 by creating maps to visualize these changes
* Identify flood waters using satellite imagery and produce a map of historical floods in Fairfax County
* Communicate flood risk to a wide audience, including residents of Fairfax County, using an ArcGIS StoryMap

**Partner Overview**

***Partner Organization:***

|  |  |  |  |
| --- | --- | --- | --- |
| **Organization** | **POC (Name, Position/Title)** | **Partner Type** | **Boundary Org?** |
| **Fairfax County, Department of Public Works and Environmental Services** | Craig Carinci, Director of Stormwater Planning; Laurel Shultzaberger, Emergency Management and Safety Coordinator; Catie Torgersen, Project Manager, Stormwater Management Division; Yeoanny Venetsanos, GIS Services Manager; Juan Reyes Assistant Director; Chip Galloway, GIS Analyst; Saurabh Raje, Engineer; Camylyn Lewis, Civil Stormwater Engineer; Katherine Herman, Environmental Planner  | End User | No |

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

The Fairfax County Department of Public Works and Environmental Services is staffed with stormwater managers and planners, emergency management and safety coordinators, GIS specialists, and civil engineers who are experienced in spatial analyses utilizing remote sensing data. Our partners at the Dept of Public Works use previously collected data, expert knowledge, and flood condition assessments to inform their decision-making regarding flood planning and response. Currently, they are exploring different flood mitigation techniques such as improved stormwater conveyance systems, upgraded road culverts, and administrative provisions to promote redevelopment. These implementations are prioritized according to the 1997 Policy for Prioritizing Stormwater Control Projects for Funding Consideration. Our partners do not currently utilize NASA Earth observations, but see a great opportunity to do so in promoting data-driven and targeted flood responses.

**Earth Observations & End Products Overview**

***Earth Observations:***

|  |  |  |
| --- | --- | --- |
| **Platform & Sensor** | **Parameters** | **Use** |
| **Landsat 7 ETM+** | Surface reflectance | Surface reflectance data was used to map historical flood extent in the study area from 2000 – January 2020. |
| **Landsat 8 OLI** | Surface reflectance | Surface reflectance data was used to map historical flood extent in the study area from 2013 – January 2020. |
| **Sentinel-1 C-SAR** | Backscatter | SAR data was used to map historical flood extent in the study area from 2015 – January 2020 at a 10 m resolution. |
| **Sentinel-2 MSI** | Surface reflectance | Sentinel-2 imagery was used to map historical flood extent in the study area from 2015 – January 2020 at a 10 m resolution. |

***Ancillary Datasets:***

* USGS National Land Cover Database (2006, 2008, 2011, 2013, 2016) – land cover and percent impervious surface cover for use in synthetic LULC raster datasets
* USDA Natural Resources Conservation Service Gridded Soil Survey Geographic Database (gSSURGO) – soil type information for analysis of land use changes and potential impacts on runoff
* Flood Complaint Locations (2/3/1987 - 2/7/2021): Shapefile provided by Fairfax County containing points of flood locations over the past few decades used for training and validating the random forest classifier for susceptibility map
* USGS National Elevation Dataset (NED) – Used for calculating slope and elevation for susceptibility mapping
* Global 30 m Height Above Nearest Drainage (HAND) Web App – Used for extracting HAND data for study area

***Software & Scripting:***

* Esri ArcGIS Pro 2.7 – creation of flood susceptibility map, impervious surface change map, tree canopy change map
* Google Earth Engine – raster and data processing for flood factors and visualization of flood susceptibility map; scene inspection for historical flood mapping
* RStudio 1.4 – training and validation of random forest classifier for flood susceptibility map
* Hydrologic Remote Sensing Analysis for Floods (HYDRAFloods) (POC: Kel Markert, University of Alabama and SERVIR) – historical flood mapping

***End Products:***

|  |  |  |  |
| --- | --- | --- | --- |
| **End Product** | **Earth Observations Used**  | **Partner Benefit & Use** | **Software Release Category** |
| **Static Flood Susceptibility Map** | N/A | The static susceptibility map will be used to identify areas that may be in need of additional infrastructure or aid in flooding events. | N/A |
| **Historical Flood Maps** | Sentinel-1 C-SARSentinel-2 MSILandsat 5 TMLandsat 7 ETM+Landsat 8 OLI | Partners will use satellite-based flood extent maps to compare to reported flooding from historical events to evaluate whether such maps could supplement county records. | N/A |
| **Impervious Surface Change Maps** | N/A | Partners will use maps to evaluate how the county’s impervious surfaces have changed from 2001 – 2016 to understand how land cover changes might impact flood susceptibility. | N/A |
| **Urban Tree Canopy Change Maps** | N/A | Partners will use maps to evaluate how the county’s tree canopy has changed from 2001 – 2016 to understand how urban canopy changes might impact flood susceptibility. | N/A |

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

The provided maps and information will help partners understand the risk that Fairfax County faces from local flood events due to weather extremes. Education about the use and availability of remote sensing resources will allow the partners to better understand how remotely-sensed environmental factors contribute to flooding events, identify areas with a high concentration of impervious surfaces, and assist communities in planning for flood mitigation. Overall, the products will assist the partner agencies by improving their environmental management strategies to be more proactive rather than reactive.

**References**

Bartlett, R. (2019). *Fairfax County Flood Response Strategy: Options to Address Flooding and Improve Stormwater Management*. Fairfaxcounty.gov oct08-environmental-2-flooding.pdf

Cian, F., Marconcini M., & Ceccato, P. (2018). Normalized Difference Flood Index for rapid flood

mapping: Taking advantage of EO big data. *Remote Sensing of Environment*, *209*, 712-713.

https://doi.org/10.1016/j.rse.2018.03.006

Muche, M. E., Hutchinson, S. L., Hutchinson, J.M.S., & Johnston, J. M. (2019). Phenology-adjusted dynamic curve number for improved hydrologic modeling. *Journal of Environmental Management*, *235*, 403-413. https://doi.org/10.1016/j.jenvman.2018.12.115

Roopnarine, R., Opadeyi, J., Eudoxie, G., Thong, G., & Edwards, E. (2019). GIS-based flood

susceptibility and risk mapping Trinidad using weight factor modeling. *Caribbean Journal of Earth*  *Science*, *49*, 1-9.