

Landslide Susceptibility Analysis based on Citizen Reports to a 311 System

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Why estimate Landslide Susceptibility?

- Essential for mitigating risk of landslide damage.
- Safe Land-Use Planning and Prioritization of Preventative Efforts
- Identify Factors that govern landslide occurrence
- Landslide damage to infrastructure in Southwestern Pennsylvania has increased in recent years.

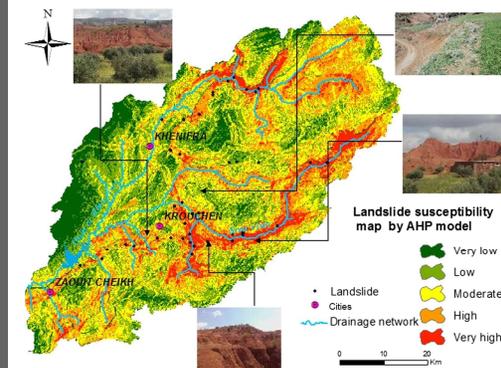


How are Landslide Susceptibility Models Made?

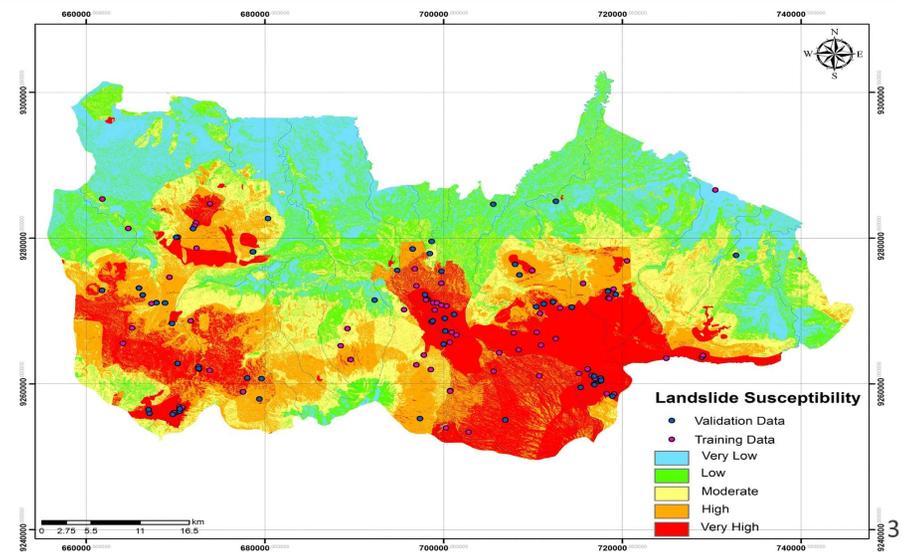
- 1) Define a study area and **create an inventory** of known landslide locations through field mapping or remote sensing methods.
- 2) Define the **geospatial and environmental factors** that have influence over the occurrence of landslides.
- 3) Build a **quantitative predictive model** of landslide susceptibility by evaluating the relationship between landslide occurrence and geospatial and environmental factors.
- 4) Validate and determine the **uncertainty** in the created landslide susceptibility model.



Pomeroiy, 1979



Silalahiet al., (2019)



Jazouli et al., 2009



Landslide Inventories

- A register of the spatial distribution of past landslide occurrences
- Allow to investigate:
 - Distribution,
 - Types,
 - pattern,
 - Recurrence,
 - Statistics of slope failures,
 - Landslide susceptibility (vulnerability and risk)
 - The evolution of landscapes dominated by mass-wasting processes.
- Commonly Created from:
 - Aerial Photography
 - Field Mapping
 - Satellite and Terrestrial Remote Sensing
 - Digital Elevation Analysis
- Can be expensive require extensive work, so commonly are not updated over time.

MAKE THE RIGHT CALL

911

- * Police and Fire Emergencies
- * Crime in progress
- * Immediate threat to life/bodily injury
- * Major property damage or loss
- * Dispatch of a squad car

... Gang- and Narcotics-related calls can be made anonymously ...

311

- * Graffiti Removal
- * Pot Hole in Street
- * Tree Trim
- * Abandoned Vehicle Complaint
- * Rodent Baiting/ Rat Complaint
- * Building Violation
- * Street/Alley Light Out
- * Sanitation Code Violation
- * Garbage Cart New, Damaged, Additional, Stolen
- * Pot Hole
- * Alley Sewer Inspection
- * Animal - Inhumane Treatment
- * Animal in Trap
- * City Program and Service Brochure Request
- * Building - Illegal Conversion
- * Bungalow Rehab/Purchase Information
- * Cable TV Complaint
- * Clean Vacant Lot
- * Clean and Green Program
- * Consumer Fraud Complaint
- * Consumer Retail
- * Dead Animal Pick-up
- * Emergency Food
- * Extreme Weather Notification
- * Fire Safety Inspection
- * Fly Dumping
- * Garbage Pick-Up
- * Home Buyer Programs
- * Hydrant Damaged
- * Ice and Snow Removal
- * Landlord/Tenant Information
- * Lead Inspection
- * Mail File
- * No Building Permit and Construction Violations
- * No Heat
- * Operating Without a Business License
- * Parking Meter, Missing or Broken
- * File a Police Report after a crime

- * Porch Inspection
- * Private Drain Program
- * Pushcart Food Vendor Problem
- * Request for Speakers
- * Restaurant Complaint
- * Senior Information, Literature, and Assistance
- * Senior Well Being Check
- * Sewer Cleaning Inspection
- * Sidewalks Cracked or Broken
- * Street or Traffic Signs - Missing or Damaged
- * Stray Animal
- * Street Light Pole Damage or Pole Door Missing
- * Street Lights All Out
- * Street Lights On Days
- * Tax Assistance
- * Tree Debris
- * Tree Planting or Removal
- * Vacant/Abandoned Building
- * Viaduct Cleaning
- * Viaduct Lights Out
- * Water - Low Pressure
- * Water in Basement
- * Water on the Street
- * Weed Cutting
- * Wire Basket

... and more!

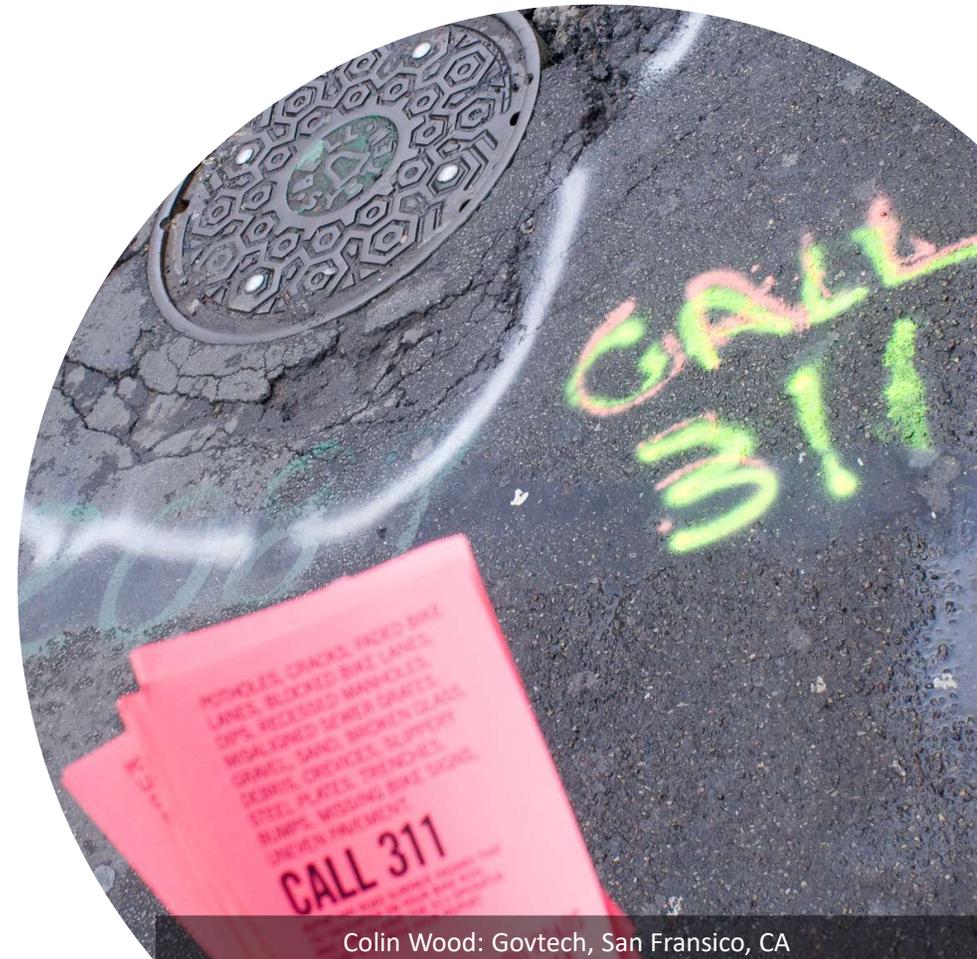
Just call 3-1-1 and ask or visit: www.chicagopolice.org

What is the 311 System?

- Non-emergency phone number
- Allows citizens to notify non-emergency municipal services of a variety of issues
- System in place in over 300 cities in the United States and Canada

What are the Potential Benefits of a 311 based Landslide Inventory?

- Publicly Available
- Updates real-time
- Records location and time of when event was reported
- Low-cost and effort



Colin Wood: Govtech, San Francisco, CA

What is the Uncertainty in 311 Data?

- Because the data collection is done through a citizen reporting systems there can be significant inaccuracy
- Privacy of citizen reporting the event
- Error in reported location from the citizen
- Reporting street intersections instead of location of landslide event

Research Goals

01

Quantify the
Accuracy of 311
Reported Locations

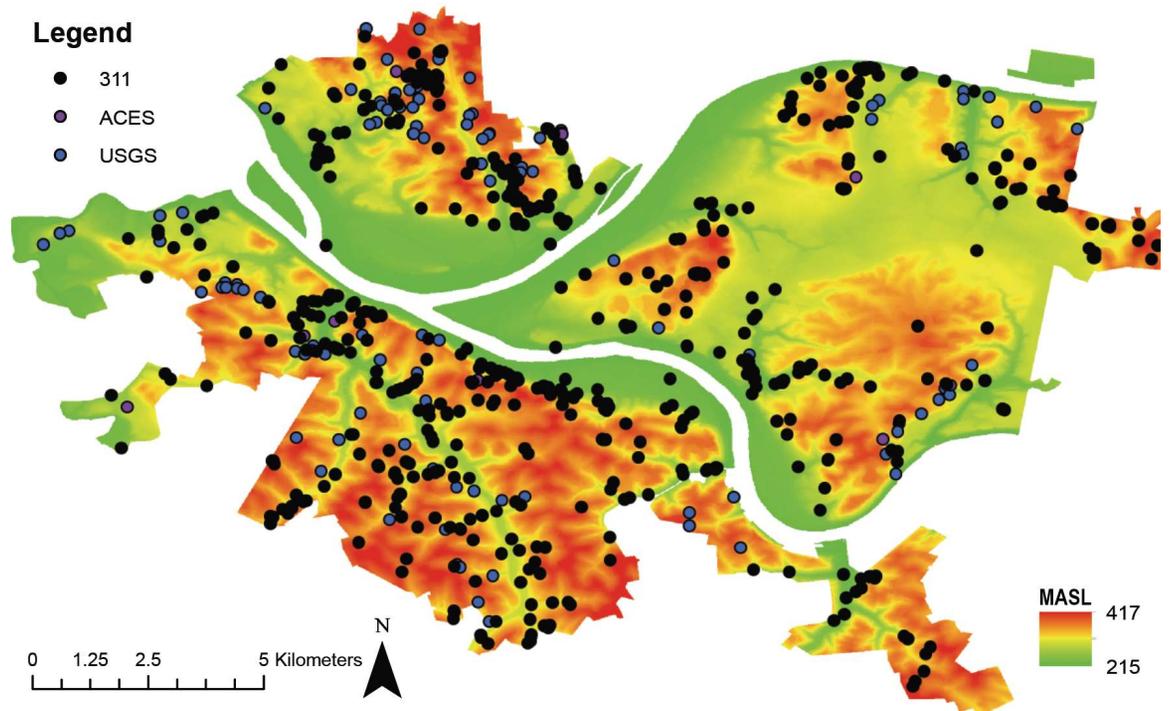
02

Quantify the
consistency of 311
data with other
landslide inventories

03

Produce a High-
Resolution
Susceptibility Map
for Pittsburgh, PA

Landslide Inventories in Pittsburgh



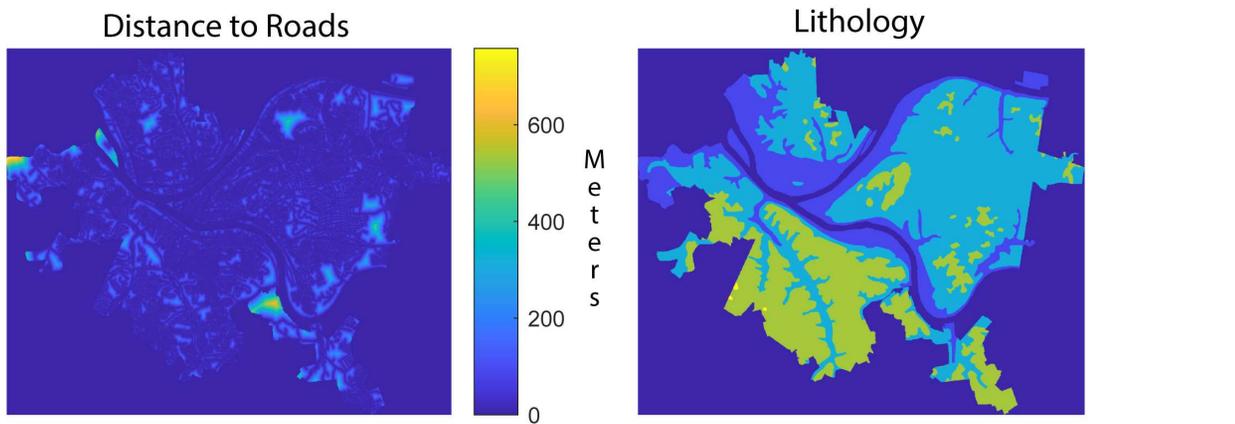
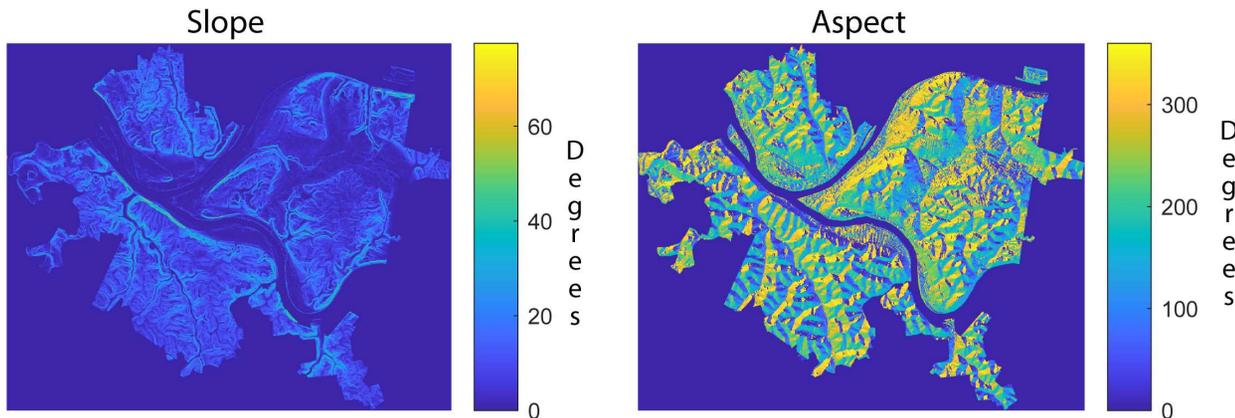
Inventory	USGS (1970-1980)	ACES (2019)	311 (2015-2020)
Number of Landslides	110	24	720
Collection Method	Field Mapping	Field Mapping	Citizen Reports

Goal 1: Quantifying Accuracy of 311 Reported Locations



- Validated Landslide Locations reported to 311 May – August 2019
- 55/77 Locations Visited Contained Landslides
- 7 Duplicate Reports of the Same Landslide
- Mean distance away from reported location 104 ± 25 meters

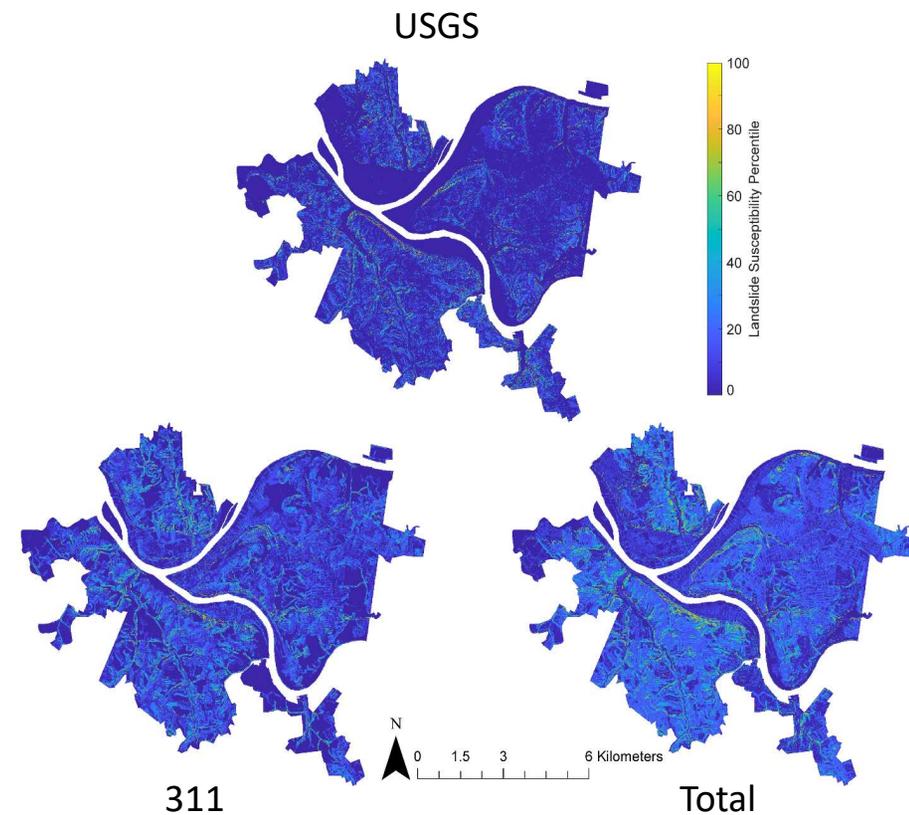
Factor Maps



1. Slope
2. Elevation
3. Aspect
4. Position on Hillslope
5. Lithology
6. Distance to Nearest Stream
7. Distance to Nearest Road
8. Profile Curvature
9. Drainage Area
10. Land-Use

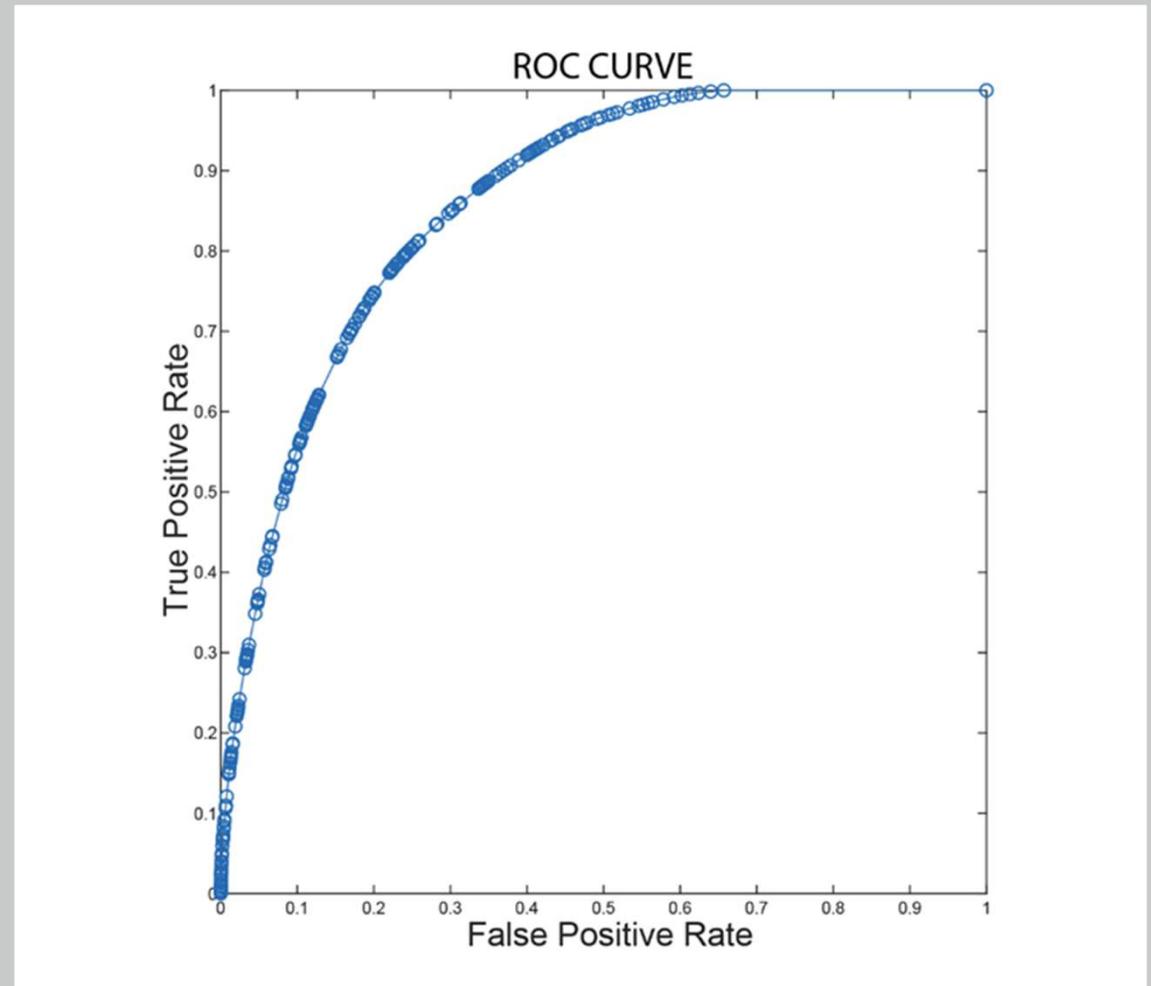
Conditional Probability (C_p)

- C_p quantifies the association between landslide occurrence and different combinations of influential factors and examines the combined influence of multiple influential factors.
- To calculate C_p the influential factors are divided into 5 factor classes that span the range of values of the factor in the study area and a C_p value is calculated for each factor class combination.



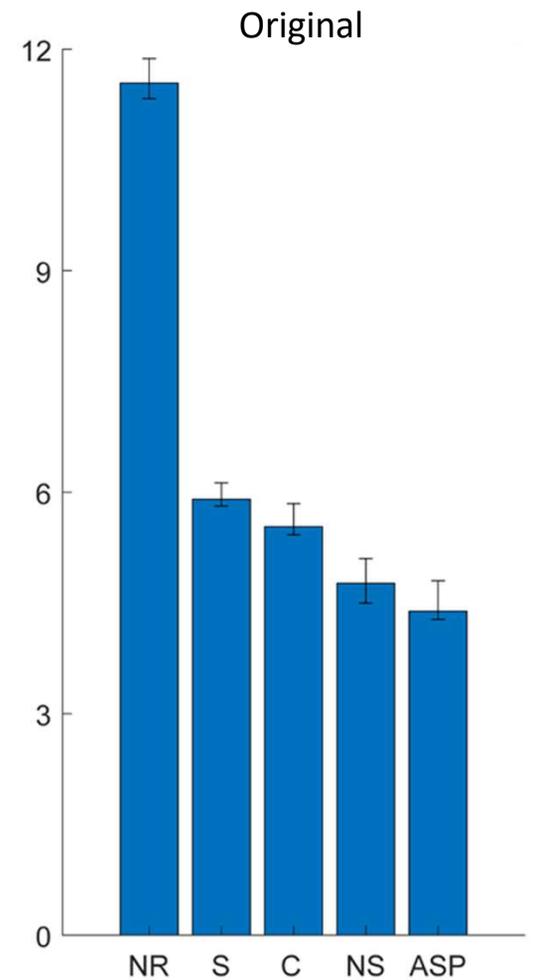
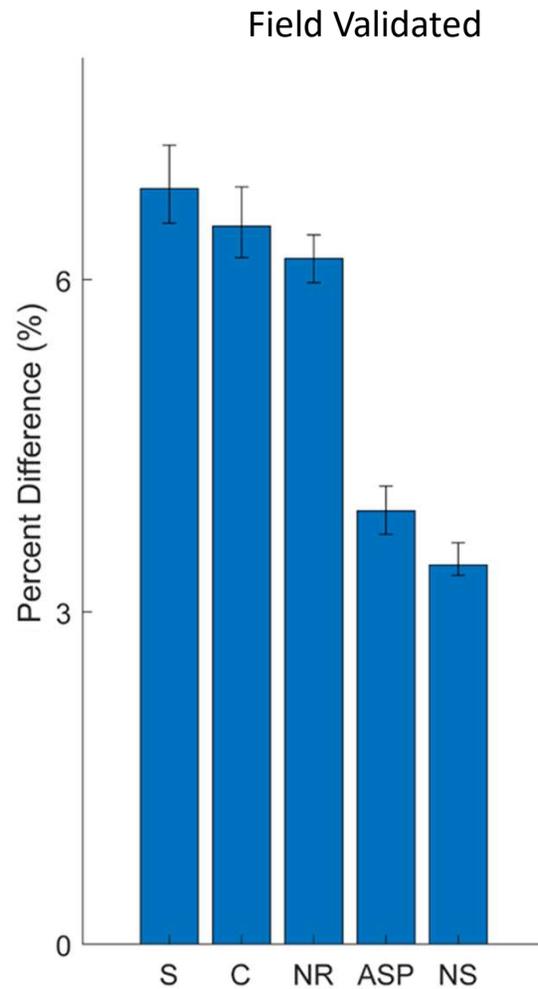
Model Validation

- Receiver Operating Curve (ROC) and Area under the Curve (AUC) Validation
- Quantitative Model Assessment for evaluating and comparing predictive models.
- Probability that the model predicts a landslide where a true landslide indeed occurs.
- AUC varies from 0-1



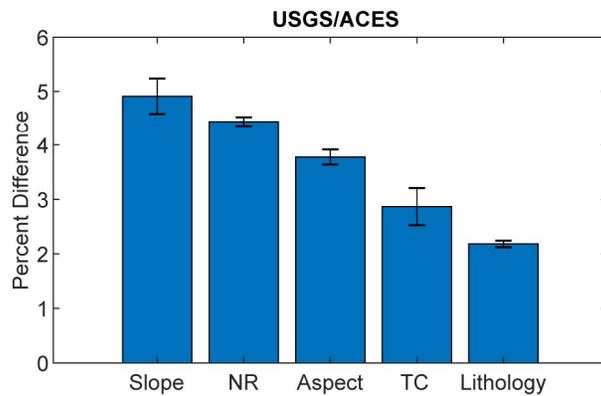
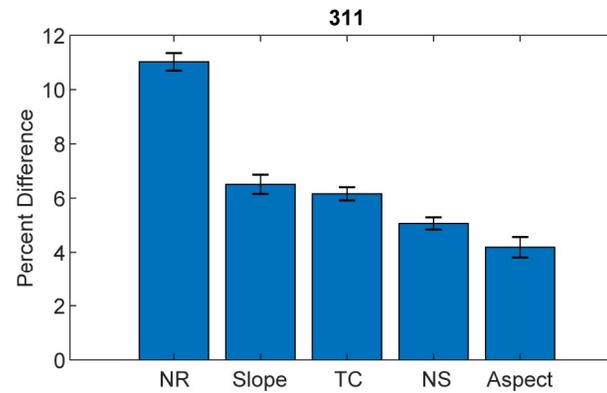
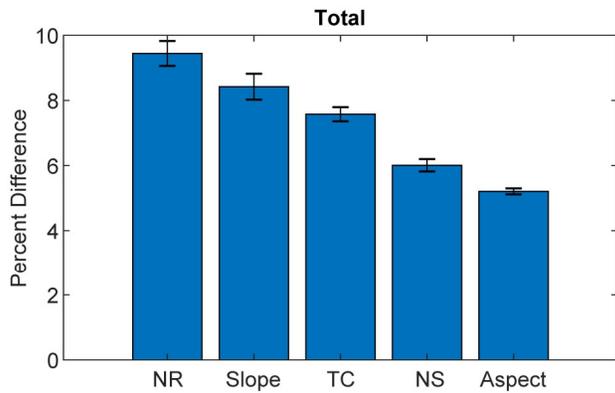
What are the Influential Factors of Landslides?

- S = Slope
- C = Profile Curvature
- NR = Nearest Road
- Asp = Aspect
- NS = Nearest Stream

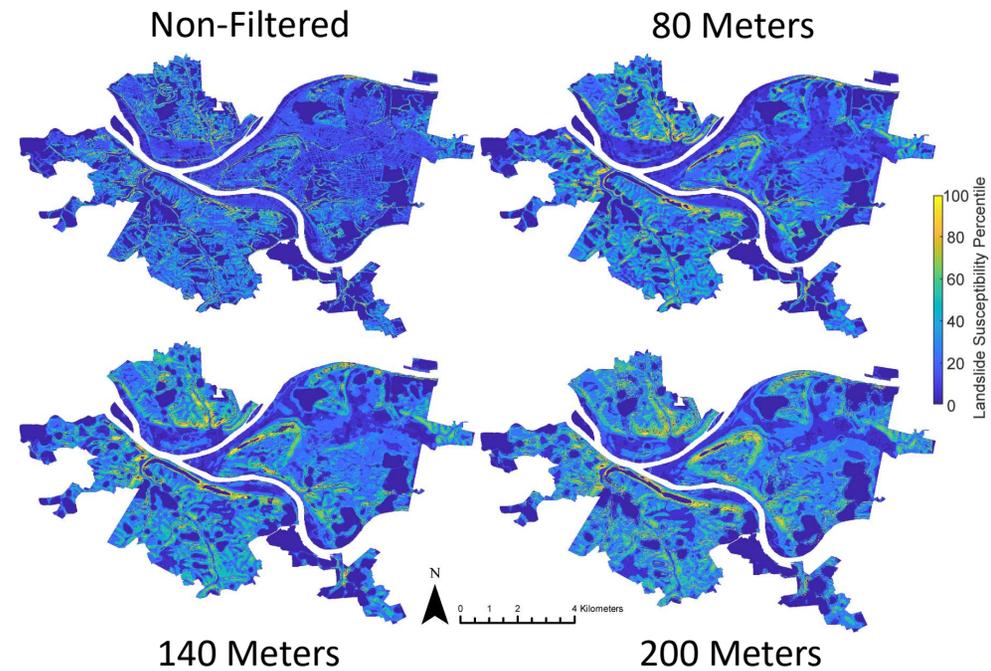
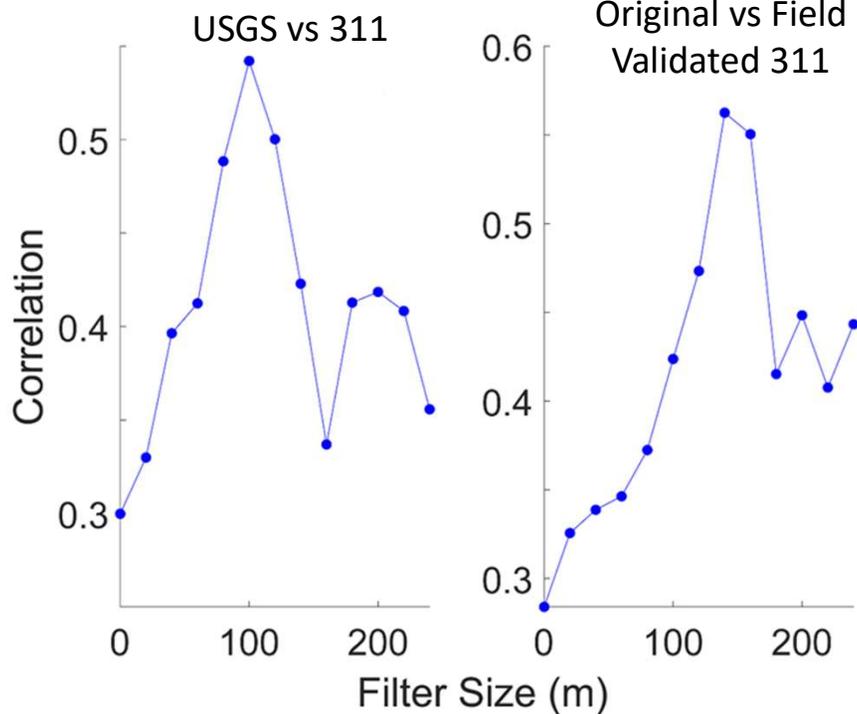


Goal 2: Consistency of 311 Data

- S = Slope
- C = Profile Curvature
- NR = Nearest Road
- Asp = Aspect
- NS = Nearest Stream
- Bias toward roads

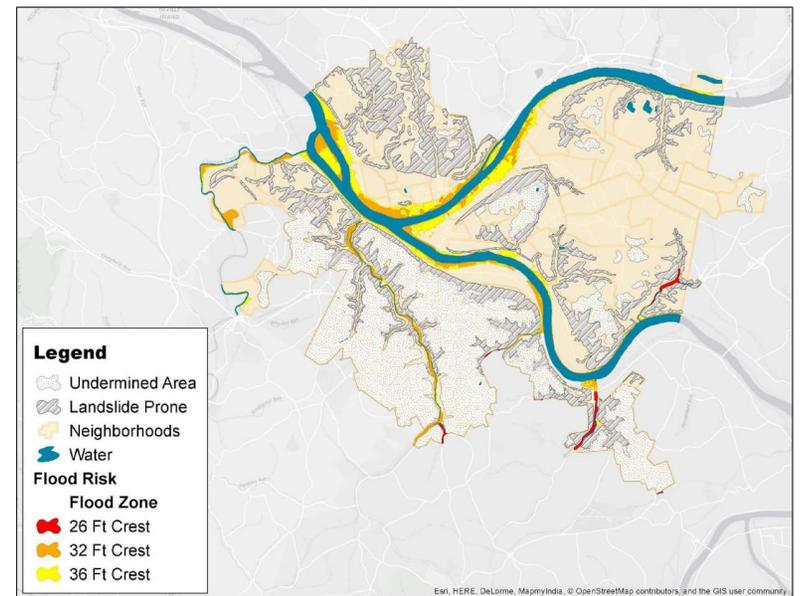
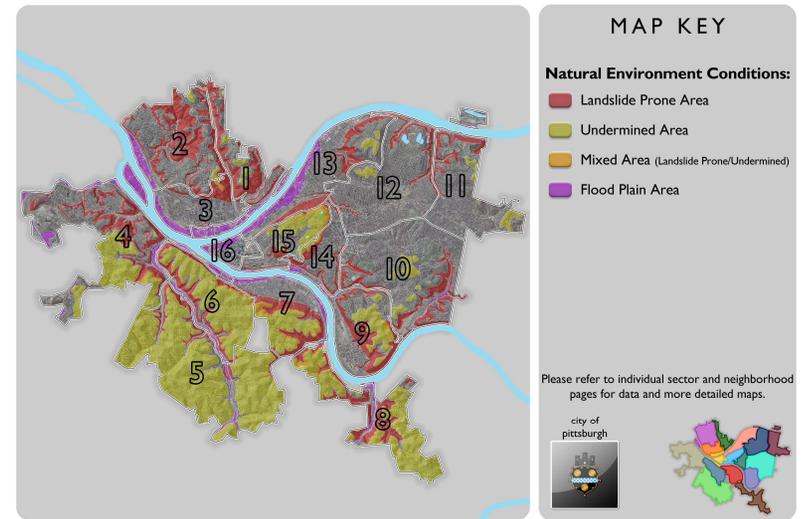
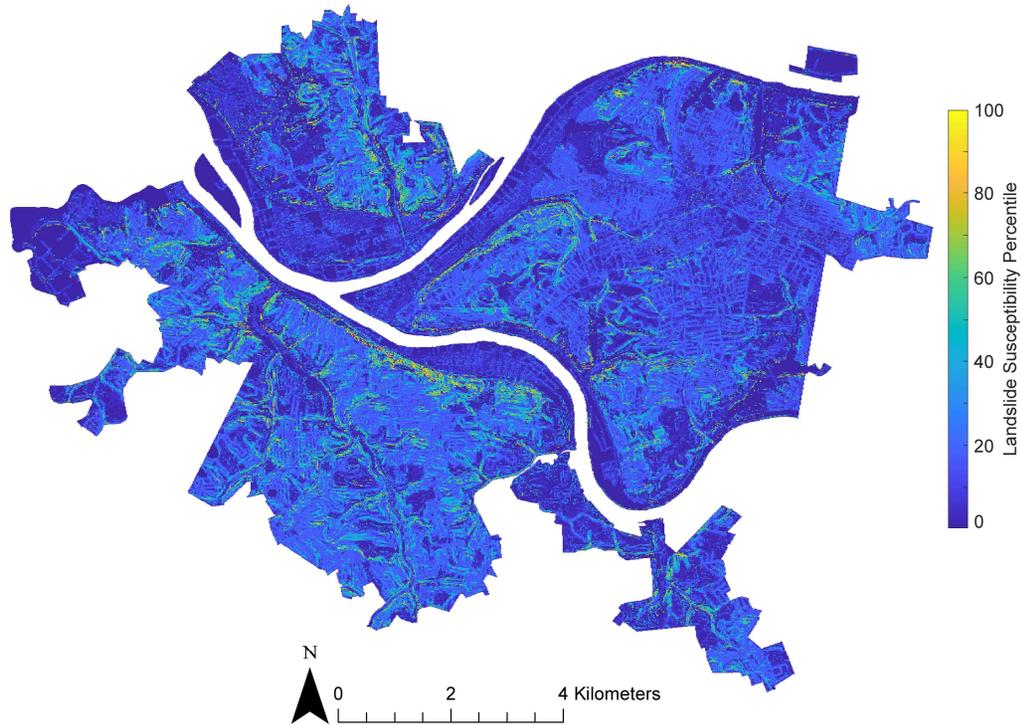


Improving the Consistency of 311 Data





Goal 3: High Resolution Landslide Susceptibility Map of Pittsburgh



Summary

- Field Validation: 104 ± 25 meters uncertainty in 311 reported locations
- 311 Data has a bias towards distance to roads, but otherwise similar influences of landslide related factors when compared to other datasets.
- Filtration improves the consistency between 311 and other landslide inventories.
- We suggest 311 can be used for high-resolution susceptibility mapping depending on project goals.



Future Work

- Further Expansion of the Validated 311 Inventory
- Use of inventory to look at temporal variables such as precipitation and temperature
- Application of Random Forest Machine Learning to Creation of Landslide Susceptibility Models

Questions?

Thank You!

Extra Slides

Weighted Contrast:

- To identify what are influential factors of landslide occurrence:
- Weighted Contrast ratio (W_c) looks at the breaks (classes) discussed either in each factor class (e.g. Slope from 5-10° will have a different W_c than 20-30°)
- Calculation for W_c : Looks at Weighted Positives (W_p) Versus Weighted Negatives (W_n)

$$W_p = \frac{\frac{A_1}{A_1+A_2}}{\frac{A_3}{A_3+A_4}}, W_n = \frac{\frac{A_2}{A_1+A_2}}{\frac{A_4}{A_3+A_4}}, W_c = W_p - W_n$$

- A1 = Number of Landslides that fell inside a class, A2 = Number of Landslides that fall outside a class, A3 = Number of map pixels that fell inside a class, and A4 = Number of map pixels that fell outside.

1. Slope
2. Elevation
3. Aspect
4. Precipitation
5. Lithology
6. Distance to Nearest Stream
7. Distance to Nearest Road
8. Profile Curvature
9. Drainage Area
10. Land-Use

Factor	Bin Edge 1	Bin Edge 2	Weighted Contrast	Frequency Ratio
Slope (Degrees)	0	1.5	-0.954910754	0.05265471
	1.5	11.28	-0.468893488	0.311181957
	11.28	21.05	3.526633159	1.995913298
	21.05	30.83	7.019137321	3.708499278
	30.83	77.49	7.259039801	3.915030513

Filtration on Landslide Factors

- S = Slope
- C = Profile Curvature
- NR = Nearest Road
- Asp = Aspect
- NS = Nearest Stream
- Lith = Lithology

A= 20 Meters, B = 80 Meters, C= 140 Meters, D= 200 Meters, E = USGS

