Using High-resolution images from UAV for BMP Analyses

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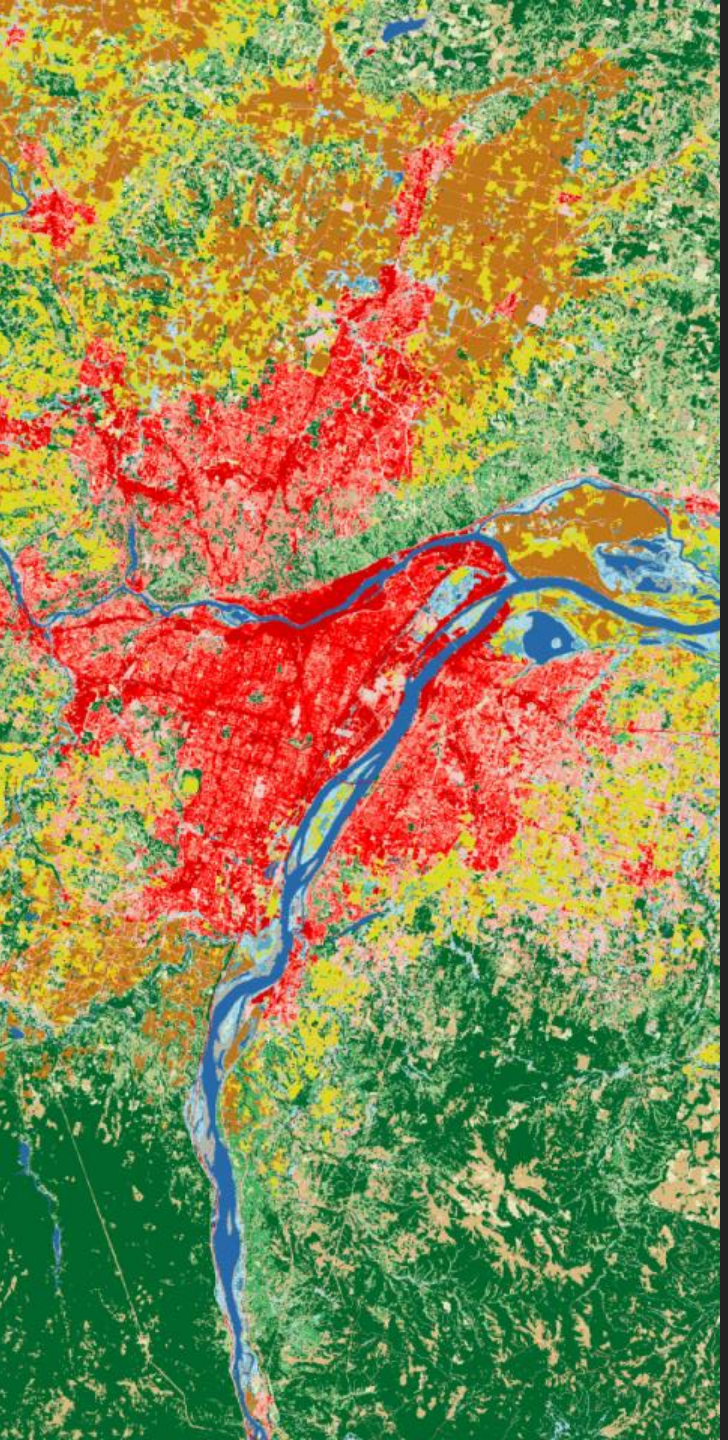


Outline

Introduction

Instruments and methods

Case study

Discussions and Conclusions

UAV

An unmanned aerial vehicle (UAV), commonly known as a **drone**, is an aircraft without a human pilot aboard.

UAVs are a component of an unmanned aircraft system (UAS); which includes a UAV, a ground-based controller, and a system of communications

Surveillance UAV

AltiGator civil drone

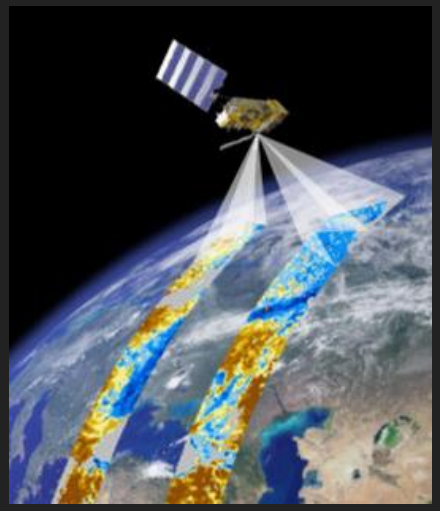
A DJI Phantom UAV

Source: wikipedia.org/wiki/Unmanned_aerial_vehicle

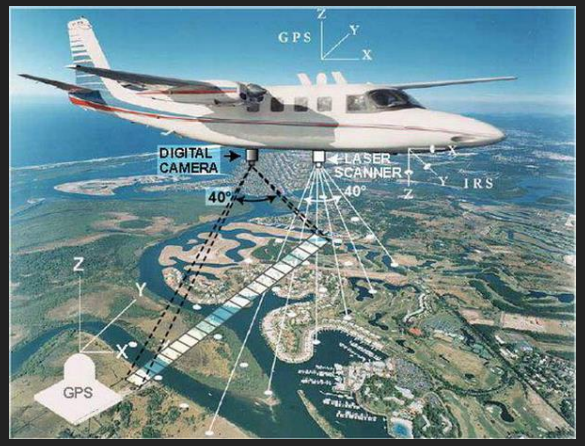
GIS and Remote Sensing

- **GIS** manages location-based information and provides tools for display and analysis of various statistics
- **Remote sensing** is the art and science of making measurements of the earth using sensors on airplanes or satellites.
- Remote sensing provides one of the most useful **data sources** for GIS analysis
- Remote sensed imagery is **integrated** within GIS

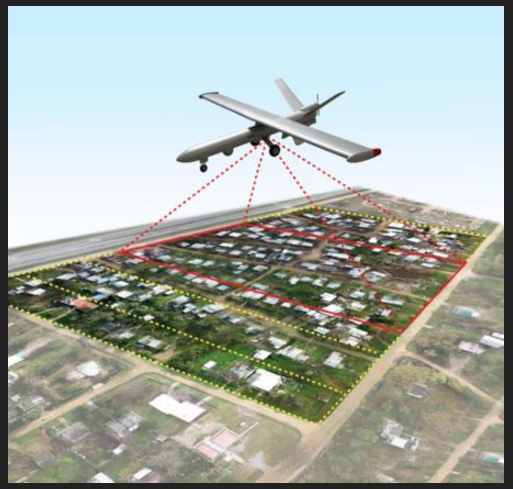
Types of remote sensing



Satellite remote sensing

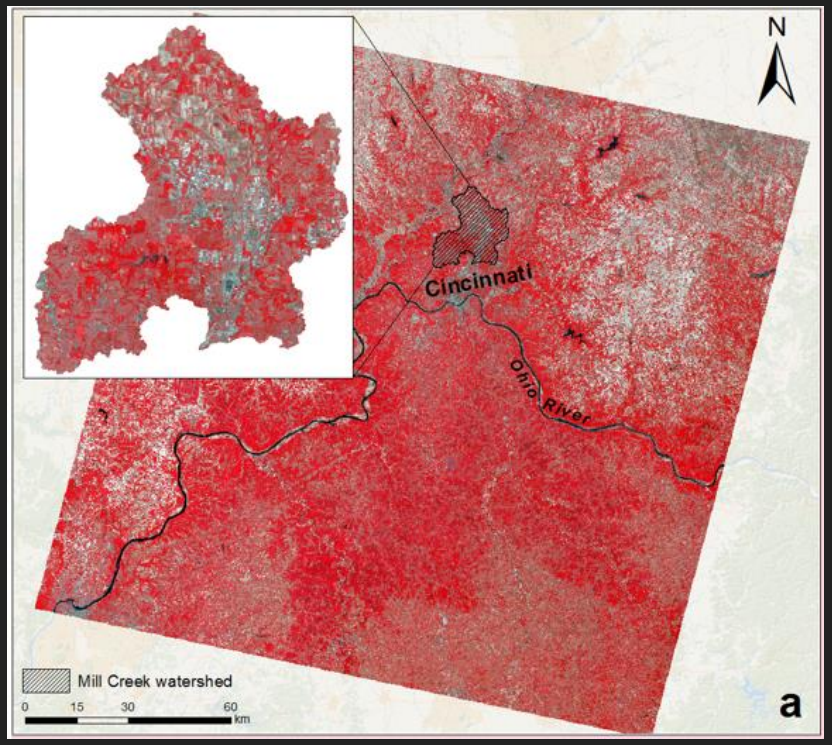


Aerial remote sensing



UAV remote sensing

Satellite remote sensing



Landsat 8 NIR false color composition multi-spectral imagery

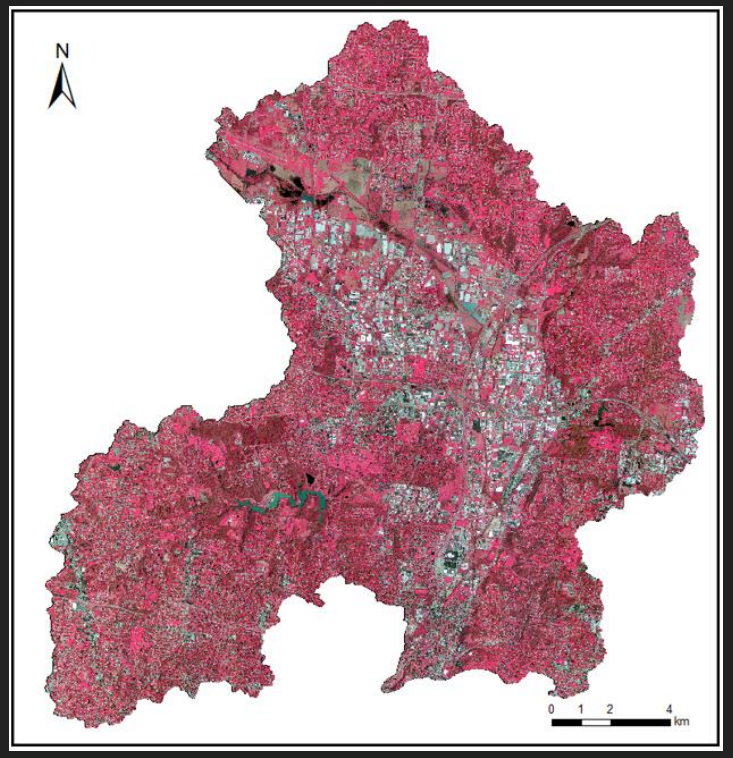
Pros

- Temporal revisiting cycle
- Historical data
- Easy to obtain
- Multi-spectral data

Cons

- Moderate spatial resolution
- Can't obtain the target day
- Cloud coverage

Aerial remote sensing



OSIP aerial imagery NIR false color combination at 1 m resolution

Pros

- High spatial resolution
- Date can be controlled
- Multi-spectral, LiDAR, Thermal sensor optional

Cons

- Expensive
- Pilot and plane needed
- Weather permitted

UAV remote sensing

USGS Drone imagery

Pros

- High spatial resolution
- Real-time data acquiring
- Easily deployed
- Affordability

Cons

- Image stitching and processing
- Data validation

UAV vs Aerial

Costs for customized UAV and camera combinations

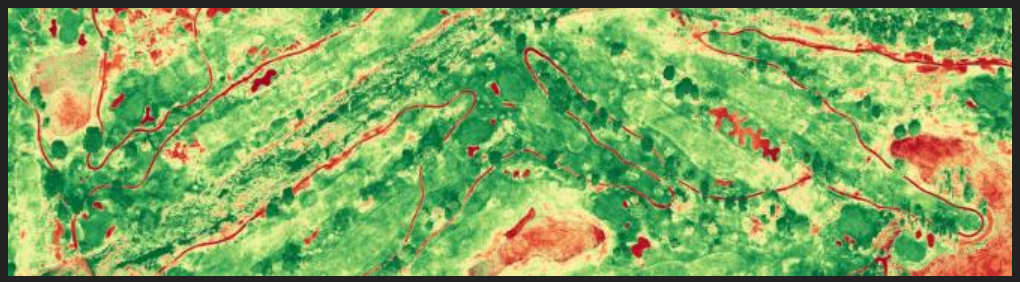
UAV and camera solutions	DJI phantom 4 Pro + Stock camera	3DR SOLO + MAPIR Cameras	DJI MATRICE 100 + FLIR VUE PRO
UAV cost	**$2,599 - $4,499**	$1700 - $2,200	$3,299 - $8,399
Camera cost	**Included**	$300 - $1,200	$1,499 - $4,499
Fly time	**28 mins**	21 mins	42 mins
Payload	**600g**	500g	1,000g

Manned aircrafts and rental rates

Types of aircraft	Very light jet	Light jet	Executive Turboprop
Aircraft example	Phenom 100, Eclipse 500	Hawker 400XP, Learjet 31A	King Air 200, King Air 90, Pilatus PC-12
Hourly rental rate	$1,750 - $2,200	$2,200 - $2,800	$1,500 - $1,850
Number of seats	2-4	6-7	3-8

Sensors

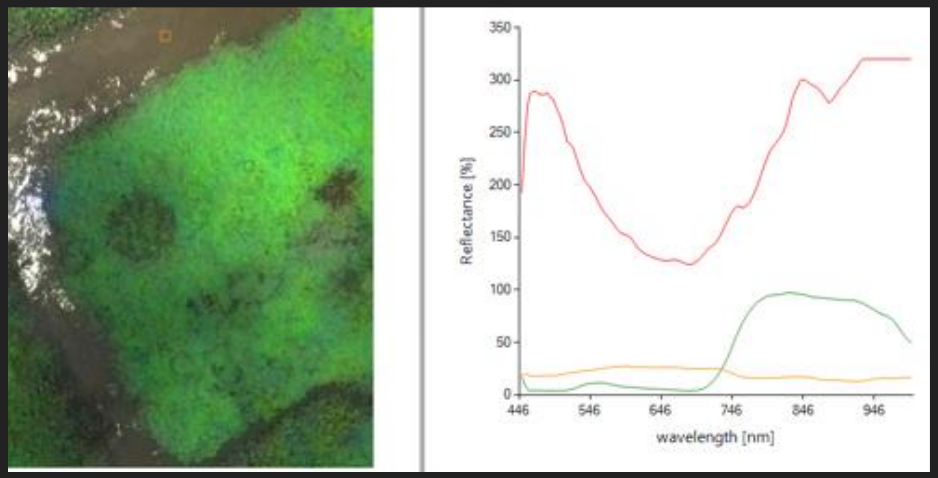
MAPIR Survey 2&3 **multi-spectral** Cameras



- 6 different filters for the Survey3 cameras: OCN, RGN, NGB, RE, NIR and RGB.
- The filters capture 3 channels of light information
- Survey 3 -- GPS embedded

Sensors

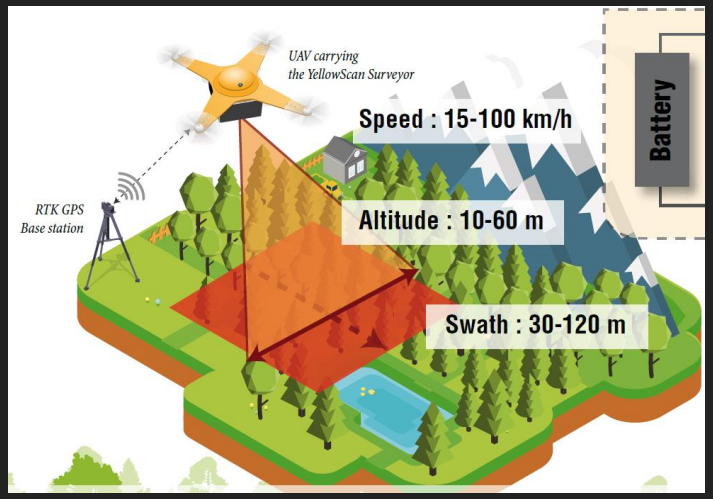
Headwall Hyperspec VNIR Turnkey Package



- Professional **Hyperspectral** Solution
  - 640 Spatial bands/270 Spectral bands
- Standard GPS included,

Sensors

YellowScan Mapper II UAV LiDAR sensor



- UAV **LiDAR** scanner
- High resolution DEM/DSM
- Accuracy: 5 cm

Image Processing

- **Esri Drone2Map**
  - Orthomosaic Imagery
  - Elevation products
  - 3D Imagery Products
  - Ground Control Points (GCPs)

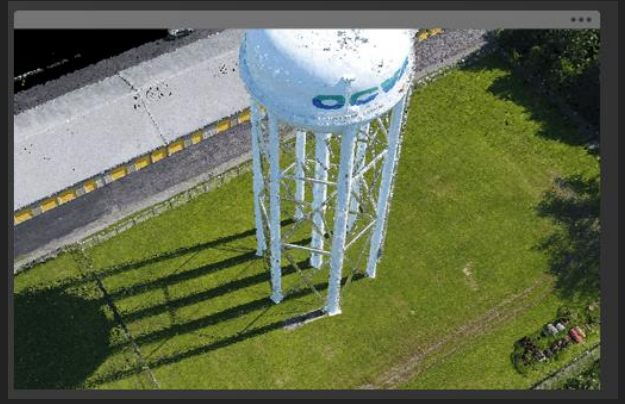
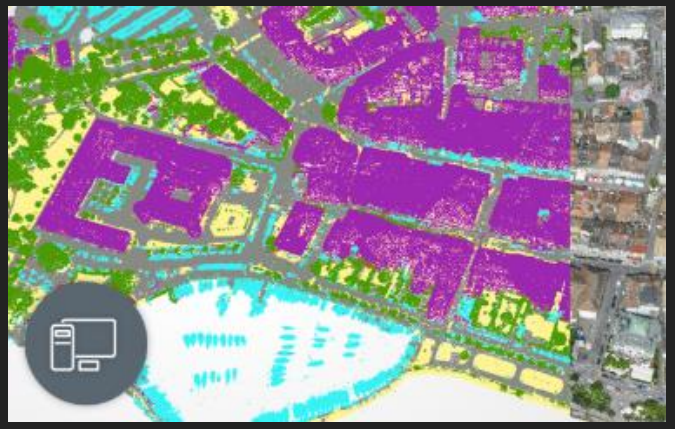


Image Processing

- **Pix4D Mapper**
  - Purely from images
  - Machine-learning point cloud classification
  - Camera self-calibration



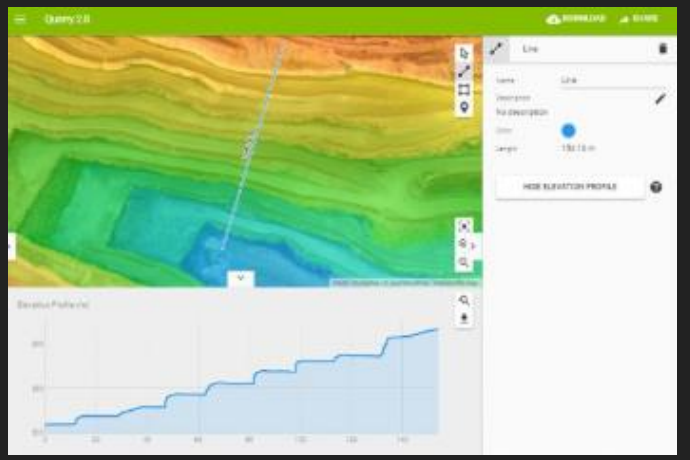


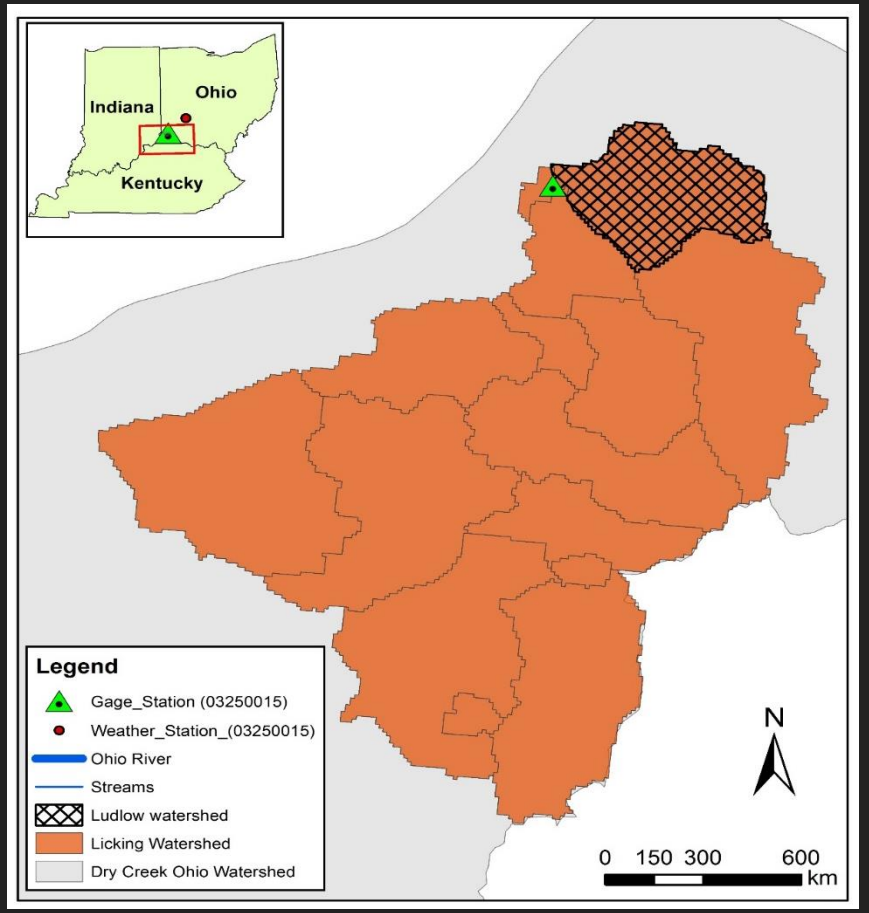
Image Processing

- **Microsoft AI**
  - State-of-the-art stitching engine
  - Support for very large image sizes
  - Accelerated stitching

    on multiple CPU cores

BMP analysis in Ludlow watershed, Cincinnati

- **Frequently flooding**
  - Narrow flood plains
  - Intensive urban development



BMP analysis for Ludlow watershed, Cincinnati

- **Previous project (Fan et al. 2017)**
  - DEM (30 m spatial resolution)
  - NLCD Land use (30 m spatial resolution)
- **New applications using UAV Imagery**
  - UAV high resolution DEM (1 m)
  - UAV Multi-spectral imagery classification (0.8 m)

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Case Studies

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DETAILS FIGURES REFERENCES RELATED

Determining the Optimal BMP Arrangement under Current and Future Climate Regimes: Case Study

Rong Fan; Susanna T. Y. Tong; and Joong Gwang Lee

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Abstract

As watersheds are urbanized, the amount of impervious surfaces will be increased. As such, water infiltration will be reduced, and the volume of surface runoff will be increased. By retaining stormwater, best management practices (BMPs) are used to mitigate the hydrologic effects of urbanization. Using the Ludlow watershed in northern Kentucky as a case study, the main objective of this paper was to identify the most cost-effective arrangement of BMPs in reducing surface runoff. A simulation

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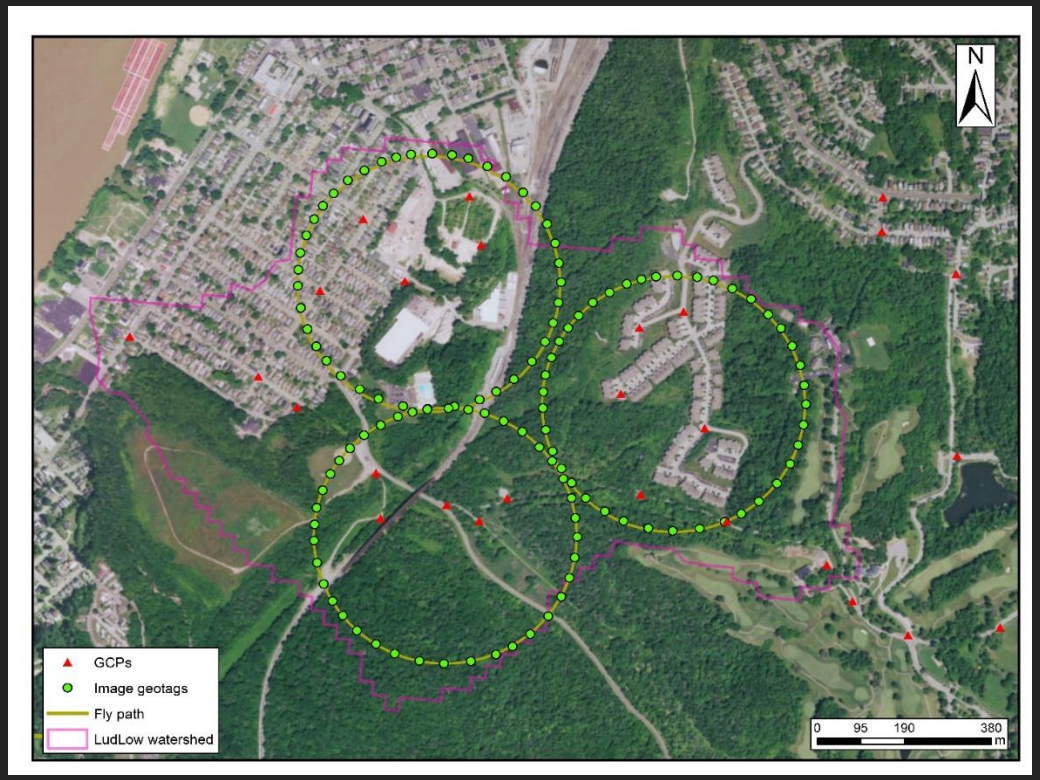
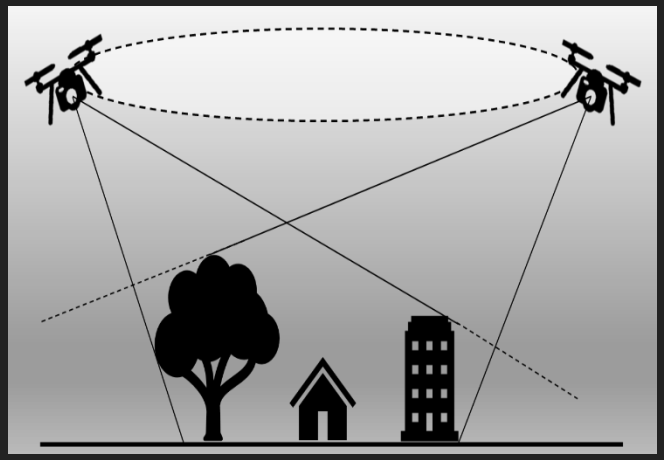
UAV high resolution data

- DJI phantom 4 Pro + MAPIR Survey 3 multispectral camera
- NIR + Red + Green + Blue

UAV high resolution data

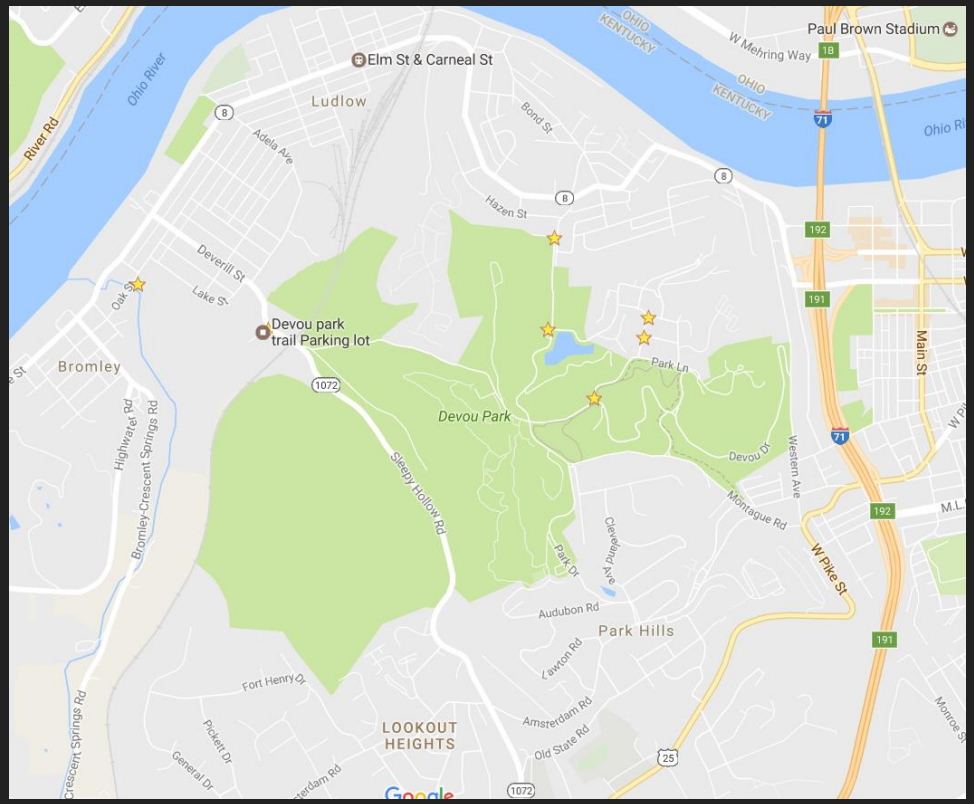




- Divided watershed to 3 sub-regions
- GCPs and fly path
- Each flight follow a route of inscribed circle of the sub-region

UAV high resolution data

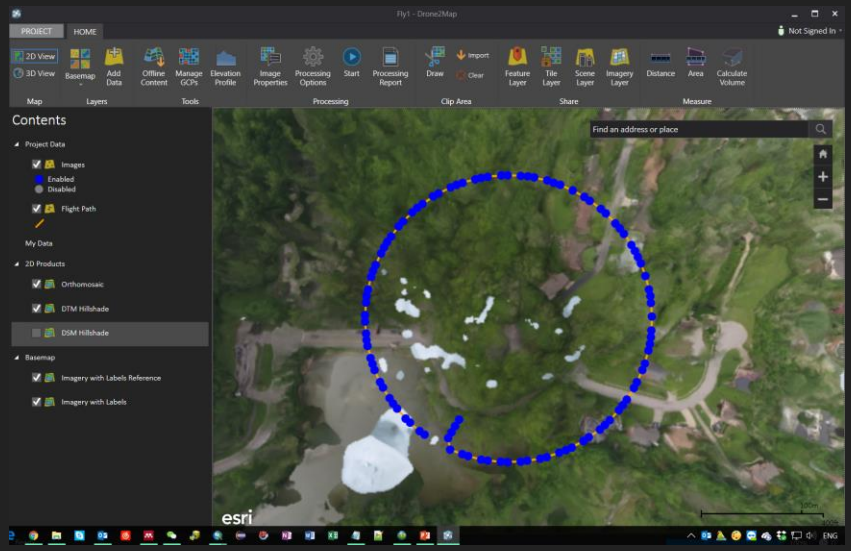
Ground Control Points (GCPs)



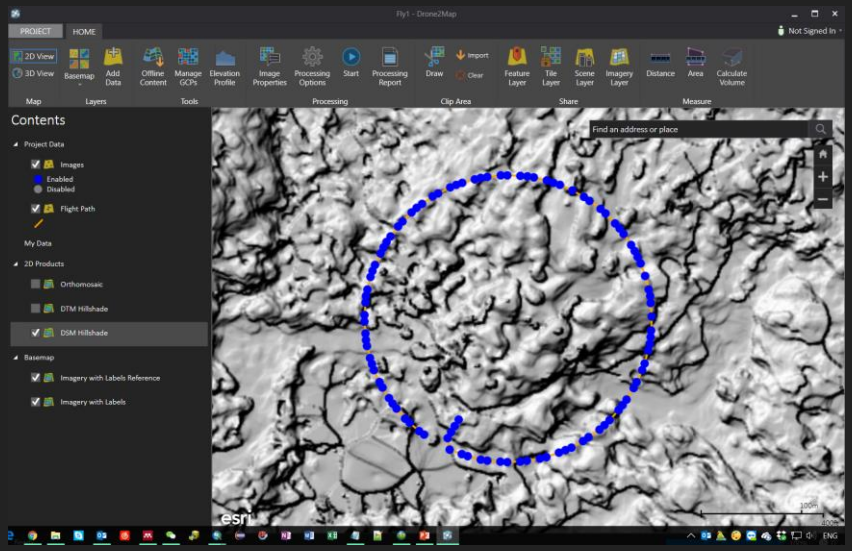
- Use GCPs to calibrate the Drone imagery
- Collected by Garmin high-performance GPS
- GPSs located in intersection of roads

UAV high resolution data

UAV image stitching and processing



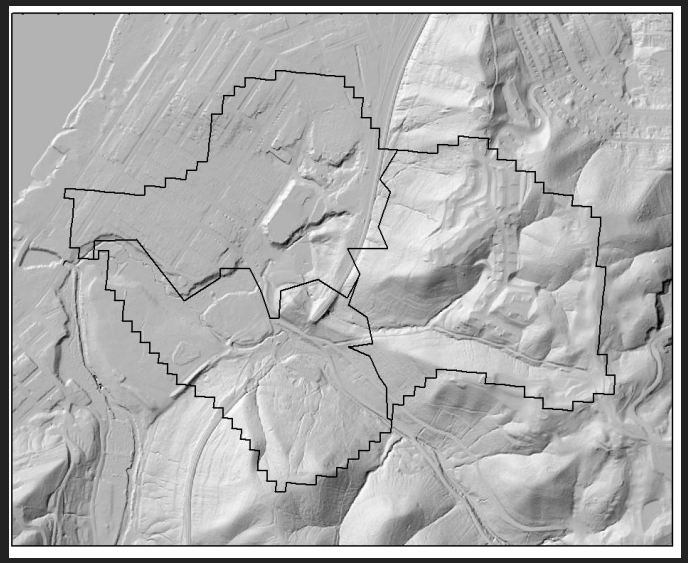
Orthomosaic image



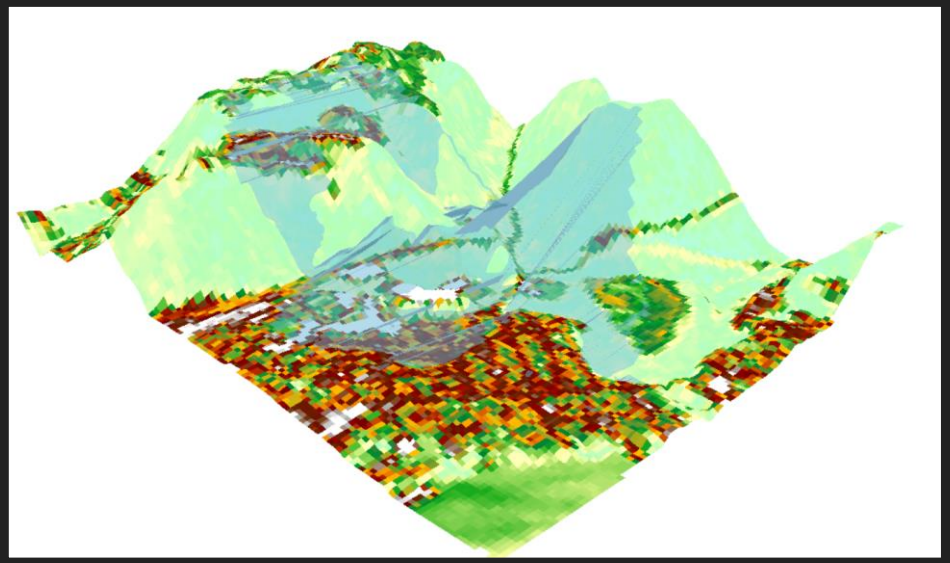
DSM Hillshade

UAV high resolution data

UAV image stitching and processing



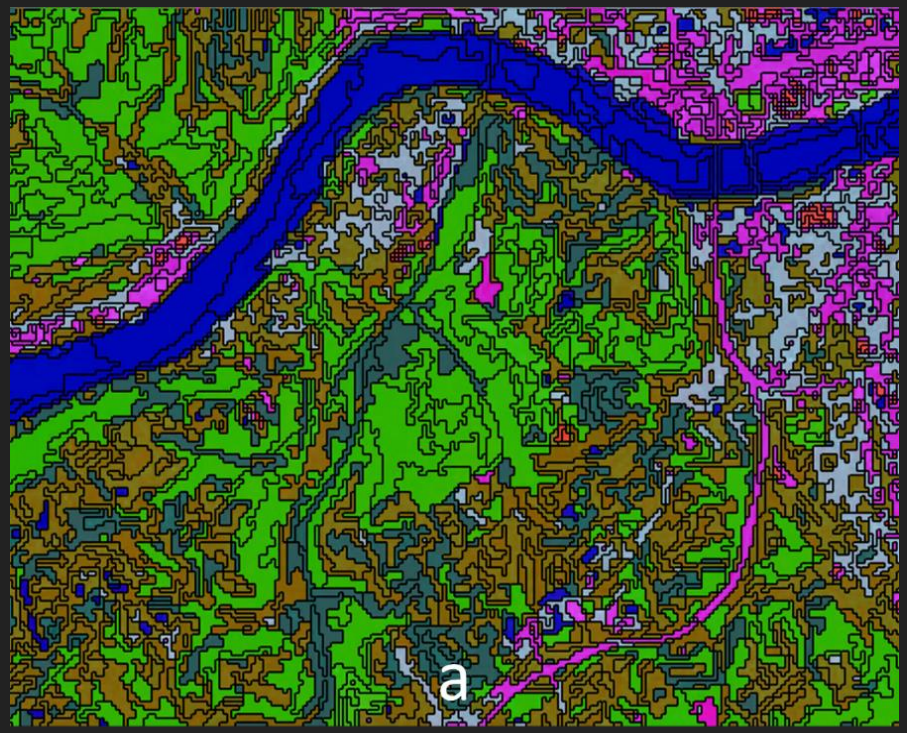
DEM Hillshade (1m)



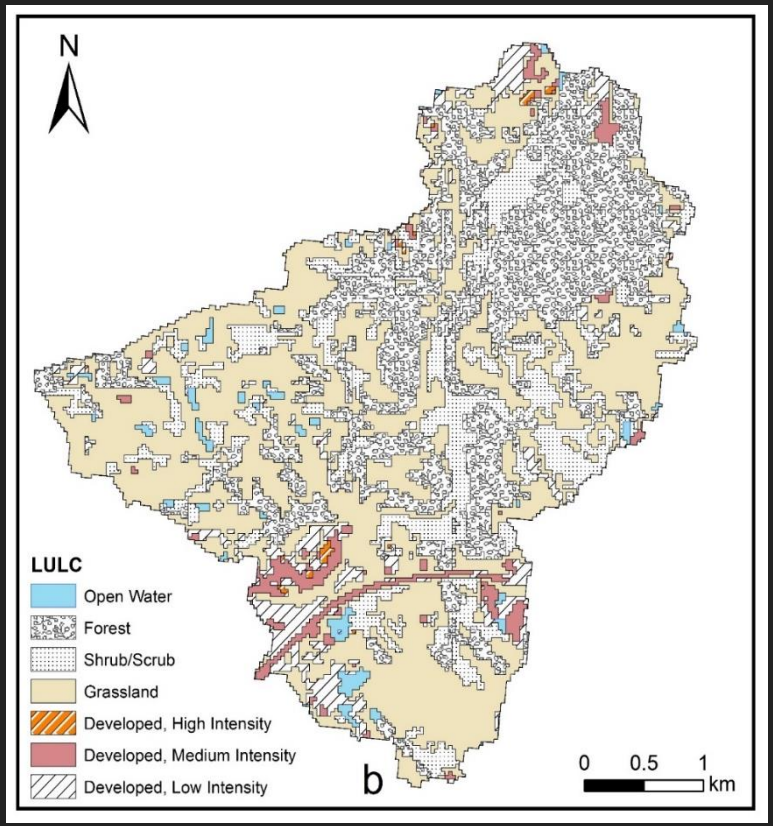
3D View of DEM

UAV high resolution data

Object oriented classification



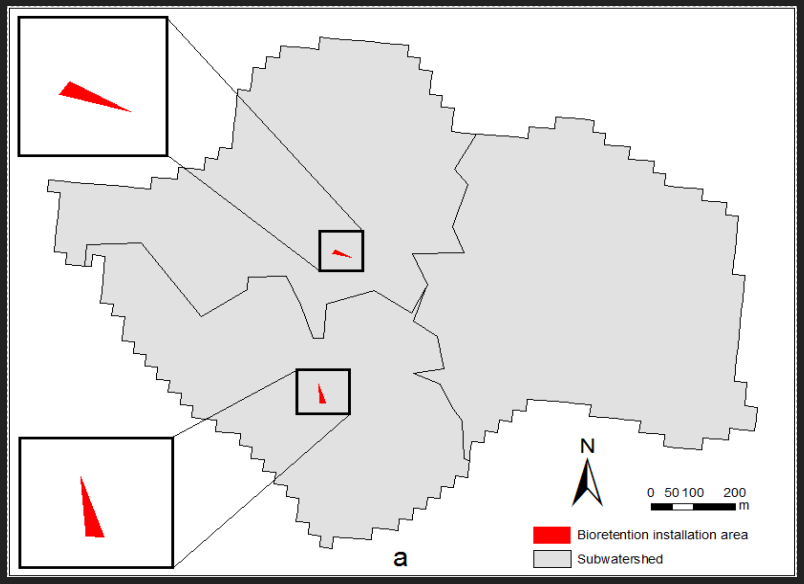
Object training samples



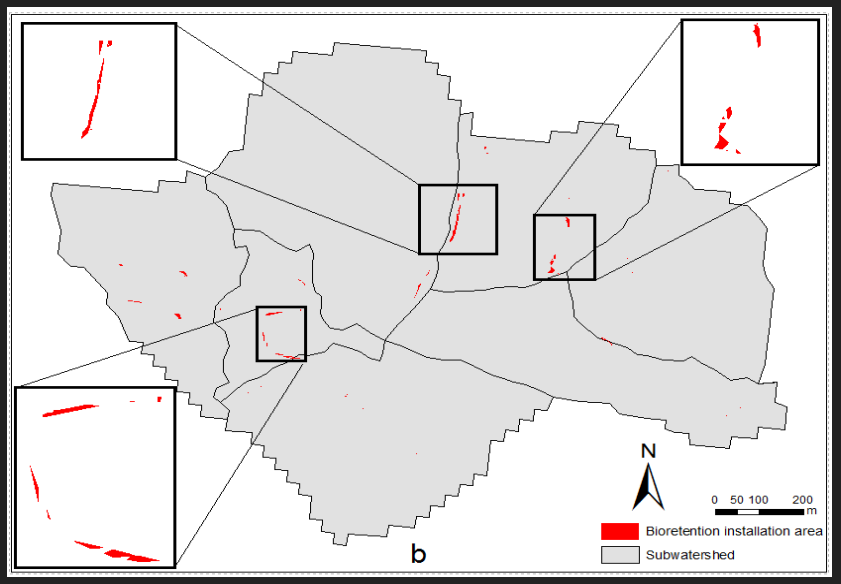
Object oriented classification results

BMP Analysis

BMP siting results for bioretention



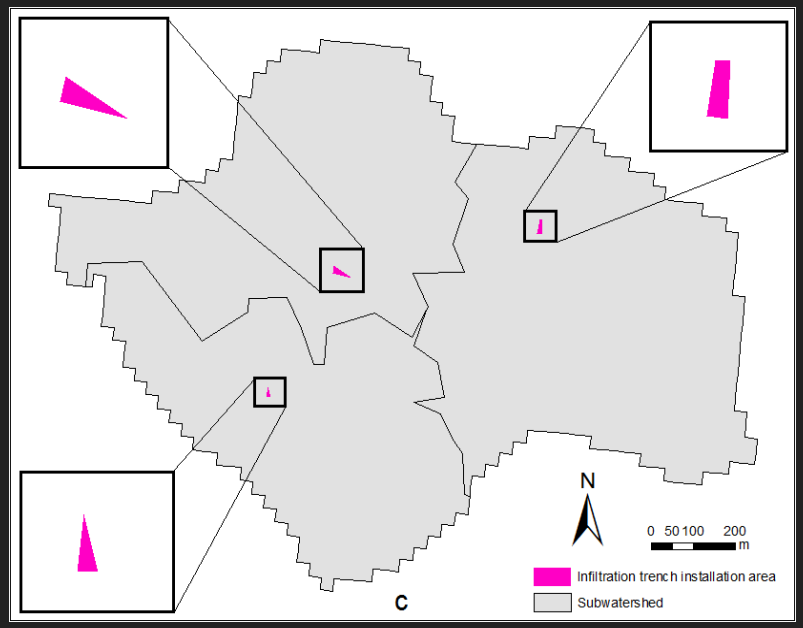
Previous BMP siting results using coarse resolution data



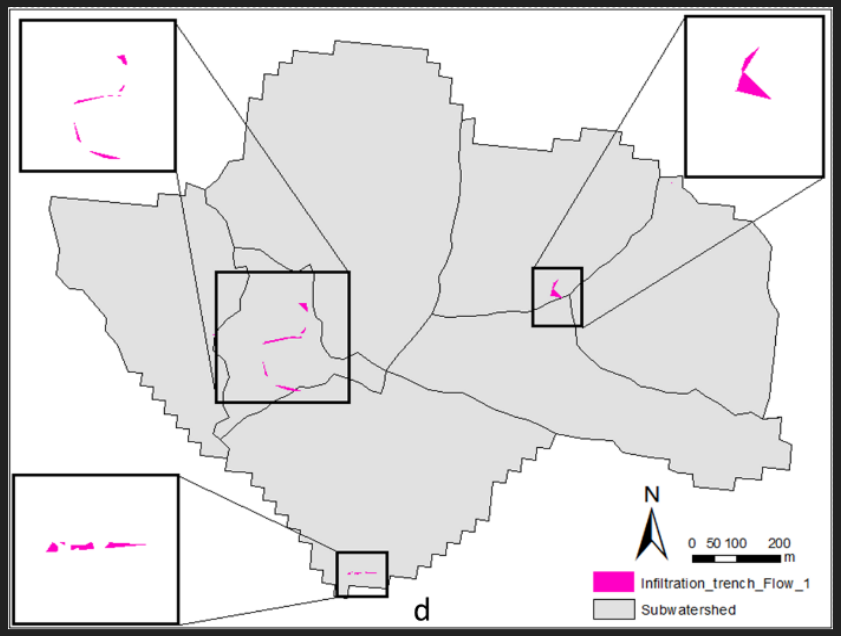
BMP siting results using UAV high-resolution data

BMP Analysis

BMP siting results for infiltration trench



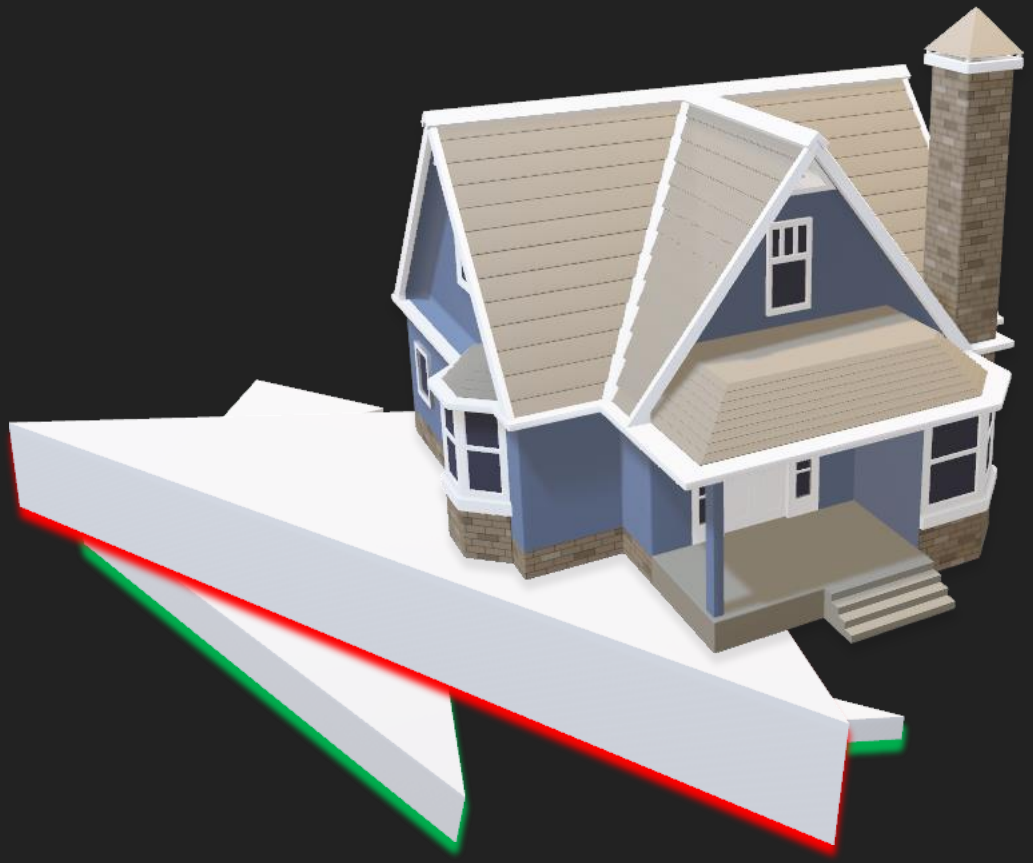
Previous BMP siting results using coarse resolution data

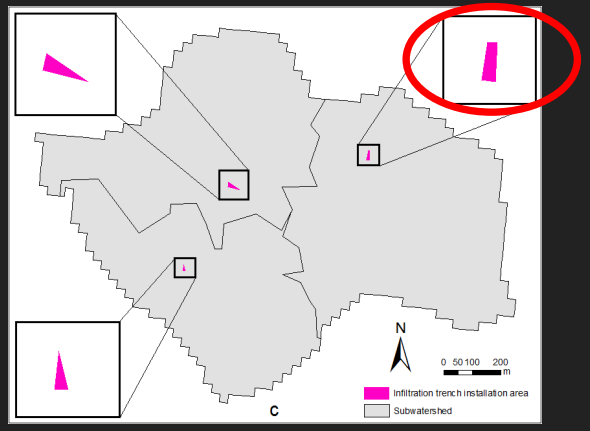


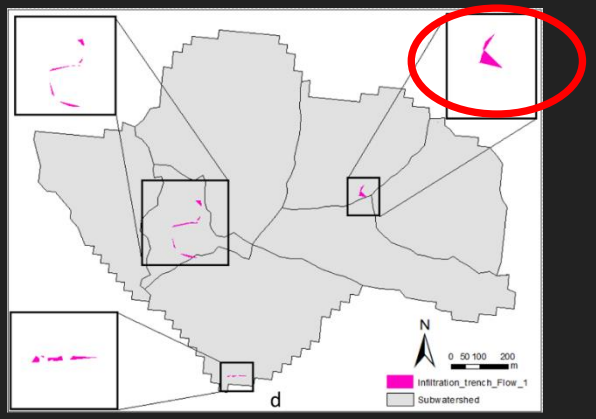
BMP siting results using UAV high-resolution data

BMP Analysis

Why high-resolution data?







BMP Analysis

Functional components for BMP installation

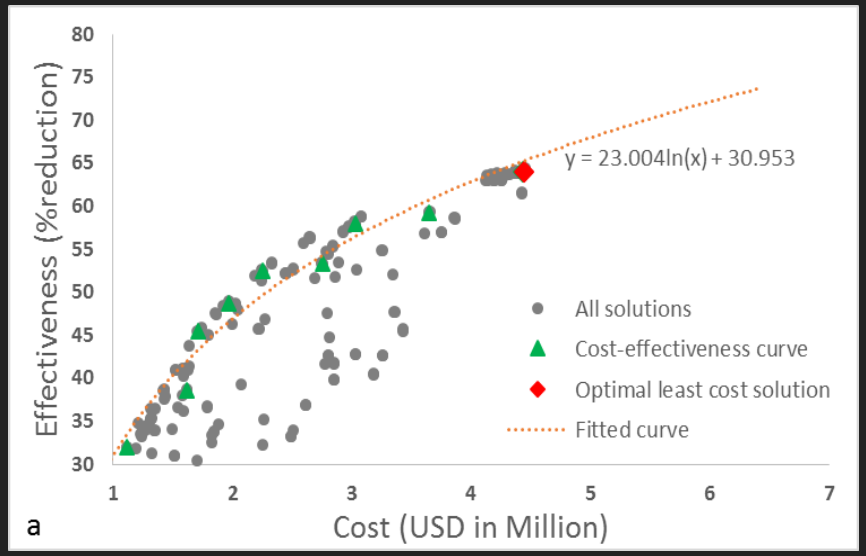
BMP components	Unit	Unit cost ($)	Source year
Excavation	m^3	5.24	2005
Grading/finishing	m^2	1.00	2005
Grass	m^2	3.23	2007
Gravel	m^3	42.12	2007
Soil/planting media	m^3	40.96	2007
Excavation & removal	m^3	55.79	2007

$$Optimize\ Cost = Min \sum_{j=1}^{m} \sum_{i=1}^{n} \left[Cost_i(Comp_{bio}) + Cost_j(Comp_{infil\ trench}) \right]$$

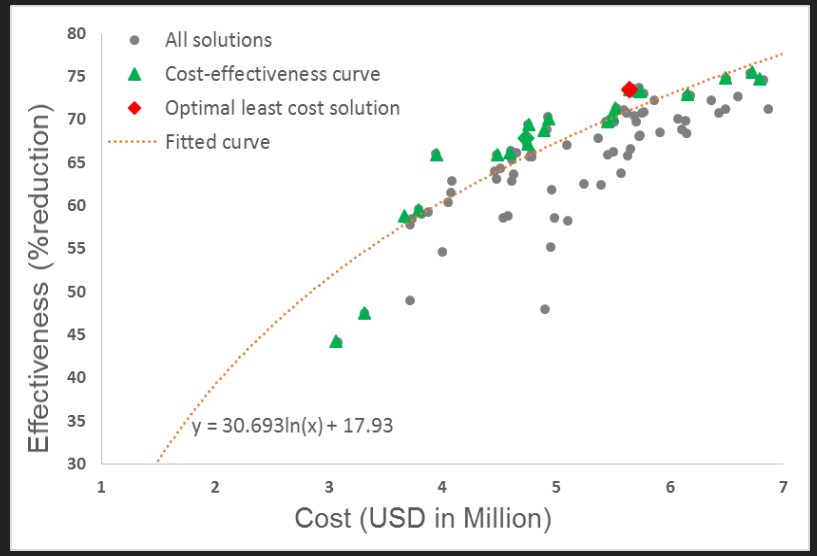
$$Flooding\ reduction_t\ (\%) = (volume_t - volume_{BMP})/volume_t$$

BMP Analysis

Flood flow reduction comparison



Previous Flood flow reduction (64%)



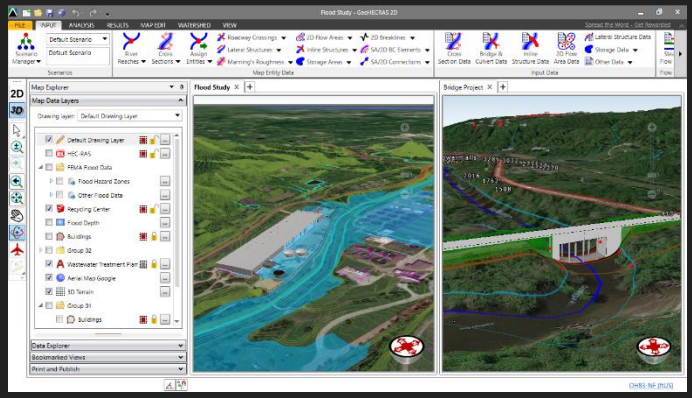
Flood flow reduction using UAV high-resolution data (73%)

What else?

- Substantial Damage Estimate
  - No field work
  - Real-time observation
  - Safety for surveyors

Damaged property in Puerto Rico

- Hydraulic modelling Survey
  - Structure identification
  - Budget-wise
  - Keep on schedule



Hydraulic modelling in HEC-RAS

Conclusions

- UAV platform is able to generate high resolution and real-time observations
- It is more affordable and easily deployed
- By customized the camera setting of UAV platform, we are able to generate multi-spectral, hyper-spectral, thermal, LiDAR measurements from UAV mapping
- Using updated UAV data, we generate more efficient and accurate BMP analysis compared with previous analysis using coarse resolution data.

Using High-resolution images from UAV for BMP Analyses

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Questions and Open Discussion

Stantec