Utilizing Remote Sensing and Machine Learning to Predict Green Infrastructure Maintenance Needs

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Background

Green infrastructure (GI) is a type of best management practice (BMP) uses natural processes to absorb and filter water, decrease water velocity, reduce sediment inflow, and store stormwater by integrating vegetation. Vegetation health is crucial to the long-term functionality of these systems. Signs of plant stress, death, or sparsity can be indications of BMP health.

Bioswale Cross-section

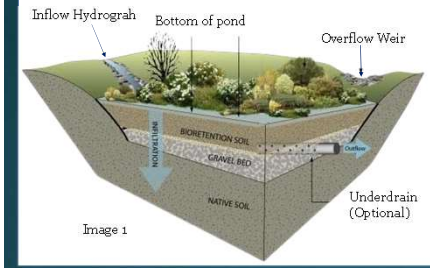


Image 1

Problem

- Municipalities have increased adoption of BMPs for their sustainability benefits, but they're lagging in maintenance efforts.
- Current maintenance processes use field inspectors who inspect each BMP individually, which requires immense time and money.

Proposed Solution

When coupled with machine learning, satellite and drone images can provide predictive analysis of GI and frequent and direct monitoring. Sensors on these objects can produce a vegetation index (NDVI) that can be used by the model to asses vegetation health.

DJI Matrice 100 Drone

MicaSense RedEdge-M Camera

Methodology & Results

1. Obtain satellite and drone images
2. Overlay images on a map and extract areas overlapping with BMPs
3. Train model to recognize different plant health classes using GIS
4. Create model that uses classified BMPs and NDVI image and run a series of tests
   1. AVG NDVI of swale < threshold → sparsity
   2. AVG NDVI of just plants < threshold → plant stress
5. Output Maintenance recommendations
6. Validate ranking model with field inspections

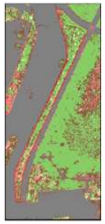
Obtained Satellite Image

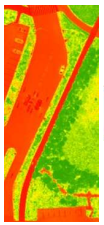
Classified satellite image

```
FORM ANALYSIS WITH CONDITIONAL STATEMENTS----
ATE THE MAINT_REQ DETERMINTION AND CORRESPOND
_path = os.path.join(Output_GDB, Dissolve_Poly
ST START WITH THE NDVI 'SPARSITY' DETERMINATI
s = ["Avg_NDVI_Swale" , "Sparsity"]
arcpy.da.UpdateCursor(table_path, Fields) as
or row in cursor:
    Avg_NDVI_Swale = float(row[0])
    NDVI_Swale_thresh = 0.3
    if Avg_NDVI_Swale > NDVI_Swale_thresh:
        row[1] = 'N' # Update the Maintenance
    else:
        row[1] = 'Y' # Update the Maintenance
    cursor.updateRow(row) # Save the changes t
    break # Exit the loop after updating the f
```

Code snippet showing conditional statement example for threshold calculations

RGB image of site area (left), training data (middle), and classified image (right).





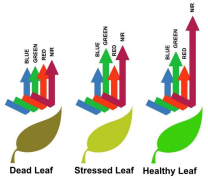


Image 2

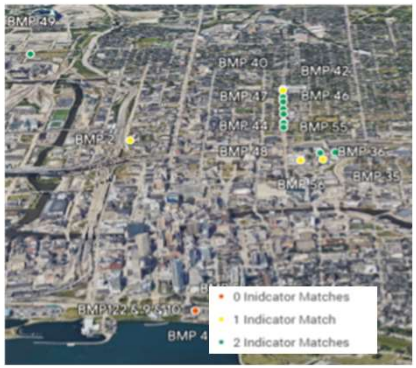
Healthy plants appear green because they reflect green light. NDVI scales measure this reflectance.

Results of Ranking Model Based on Satellite Data

OBJECTID *	Polygon_Name	Sparsity	Stressed_Plants	Avg_NDVI_Swale	Avg_NDVI_Plants	Veg_Indicator_Rank
1	BMP82	Y	Y	0.409146556547413	0.484166783006321	2
2	BMP122	Y	Y	0.418677375533545	0.452657745579794	2
3	BMP9	Y	Y	0.436923598649565	0.451790558020664	2
49	BMP79	N	Y	0.543798038815542	0.545143845640774	1
50	BMP17	N	N	0.546402719758218	0.556134876072301	0
51	BMP57	N	Y	0.548614510597418	0.530172893222293	1
90	BMP75	N	N	0.70716200849654	0.70716200849654	0
91	BMP124	N	N	0.715542777038224	0.736280314339782	0
92	BMP87	N	N	0.765164292496048	0.76523719317671	0

- Sparsity and plant stress are indicators to be evaluated.
- The best and most complex model ranked the BMPs in order of average NDVI of their swales, which indicates sparsity, one of the most important health factors.
- Including vegetation indicator rank was beneficial for glancing at the number of BMPs flagged for sparsity and stress.
- The model was applied to 92 sites within bounds of satellite data.

Comparison of Ranking Model and Field Inspections



OVERALL NOTES FOR SITE

Location Description: WAR MEMORIAL BMP Identifier: 5 BMP Type: (Bioswale/ Green Roof/ Rain Garden/ Native Plant Area/ Other)

Vegetation Condition

Inspection Item	Satisfied	Unsatisfied	Other Notes
Plant Coverage => 50% (Closer to 100% coverage for swales)	X		
Dead plants, brush, and leaves removed (No buildup)	X		
Existing plants are healthy	X		
Existing plants are alive (>75% survival rate)	X		
Minimal Weeds and Invasives Present		X	LARGE TREE WEEDS
Sum of S/U:			

Other Items

Inspection Item	Satisfied	Unsatisfied	Other Notes
No evidence of blockage of inlets or outlets(Leaves or sediment)		X	SEDIMENTATION
Overflow inlet functioning/ No water ponding	X		
No evidence of errosion/ channelization		X	CHANNELIZATION
No garbage buildup	X		
No evidence of expansive bare spots	X		
Sum of S/U:			

OVERALL NOTES FOR SITE GOOD FLOWERING

- The indicators flagged by the model were compared to similar indicators during a field inspection conducted using a GI condition assessment (image above) to confirm model results.
- 23 of 92 sites were inspected: 1 site had no indicator matches (red), 7 sites had one indicator match (yellow), and 15 sites had two indicator matches (green)
- Many BMPs marked yellow because field inspection saw that existing plants were healthy in spite of build up of brush or dead plants. The model flagged some BMPs that were actually healthy because the plant type (a more yellow plant) instead of plant health.

Field Inspections

Depicted are images from field inspections showing BMPs that were marked healthy on the model, but were considered unsatisfactory during field inspection. All of these failed inspections unrelated to vegetation health, but rather because of other GI functionality indicators.

Ponding (could indicate outlet blockage or low infiltration rate).

Erosion can deteriorate plant life and cause sediment build up.

Blockage of outlet drain due to brush. This could cause flooding if water inflow is too fast.

Abandoned construction materials knocking over plants and causing trash buildup.

Conclusion

- The model can produce accurate recommendations for some BMPs.
- Rankings for the model based on average NDVI can be automated.
- Maintenance recommendations require a complex analysis due to varying plant species and BMP sizes.

Future Work

- Bioswales and green roofs have different standards and separate models should be considered.
- Remote sensing will be beneficial, but further development needs to be done to make it more automated and efficient.
- Models need to be able to compare more specific inspection items for a more accurate recommendation.

References

Geosyntec Consultants. (n.d.). Bioretention Areas and Rain Gardens [Image]. Retrieved from https://megamanual.geosyntec.com/npsmanual/bioretentionareasandraingardens.aspx

Green Aero Tech. (n.d.). What is NDVI? [Image]. Retrieved from https://www.greenaerotech.com/what-is-ndvi/

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