UAV data upscaling for soil erosion monitoring in high-latitude rangelands, northeastern Iceland

Sebastian Yerex & Noémie Boulanger-Lapointe | Department of Geography | University of Victoria

Introduction

- Vegetation cover strongly mitigates soil erosion by providing shelter from erosive forces and support against gravity[1].
- Iceland has seen a dramatic loss of vegetation and an increase in soil erosion since human settlement in the 9th century[2].
- The primary source of erosion data for much of Iceland are manual maps produced between 1991 and 1997[3].
- This study examines the use of UAV and satellite remote sensing for soil erosion monitoring through data upscaling, in high latitude regions.

Methods

- UAV imagery and in-situ validation data collected at six field sites in northeastern Iceland
- UAV-scale random forest classification, upscaled to satellite resolution (10 m) through a *within-pixel fractional coverage* approach (a)
- Satellite-scale random forest regression (b-c)
- Erosion severity defined by field data collected by the Icelandic government (d)

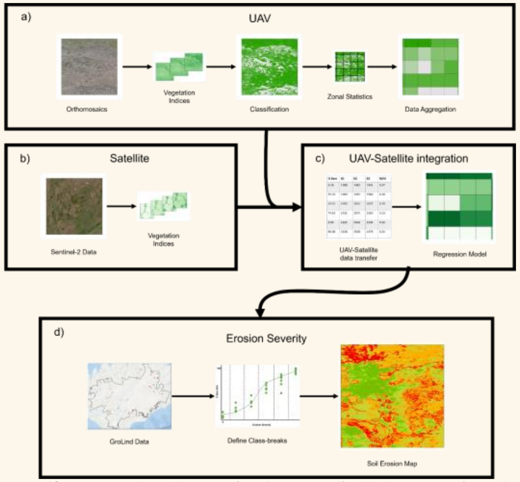


Figure 1: Workflow summarizing the upscaling process. a) UAV data processing, b) satellite data processing, c) UAV and satellite data integration for training Sentinel-2 regression model, d) using land monitoring data (GroLind) to define erosion class breaks.

Results

UAV-scale classification:

- Achieved good results across the six sites with an overall accuracy of 96.6% and kappa score of 0.95

Upscaling and satellite-scale regression:

- Some information is lost in the upscaling process due to the masking of within-pixel bare soil distribution.
- Overall, the satellite-scale regression performed well with an R^2 of 0.814
  - Site specific accuracy varies greatly (R^2 : 0.403 - 0.924)

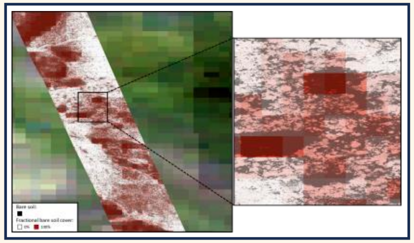


Figure 2: UAV-scale classification (black: bare soil, white: vegetated area) overlain with satellite-scale regression results shown in red to white gradient (red: 100% bare soil, white: 0% bare soil). Site 400-4.

Table 1: A summary of the validation results for UAV-scale classification at each of the six field sites and overall accuracy.

Site:	Accuracy (%):	Kappa:
Overall	96.6	0.95
400-1	97.4	0.97
400-3	92.2	0.90
400-4	96.6	0.94
400-5	98.6	0.98
500-3	97.8	0.97
500-6	97.0	0.96

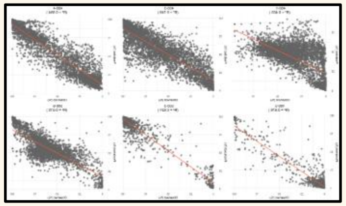


Figure 3: A series of scatterplots showing the UAV based bare soil cover (observed) and satellite-scale regression model (predicted), as well as R2 value for each field site.

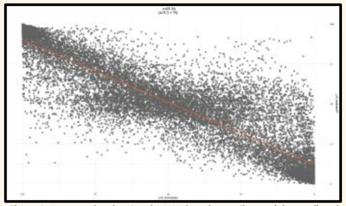
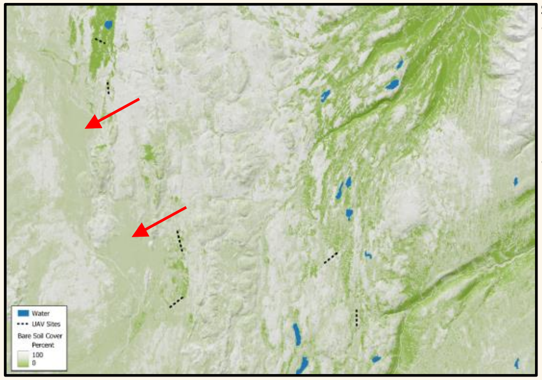


Figure 4: A scatterplot showing the UAV base bare soil cover (observed) and satellite-scale regression model (predicted), as well as R2 value for all sites.



Satellite-scale maps:

- The bare soil cover map shows good results for cover-types similar to field sites.
- Regions with dark volcanic sands, not covered by field sites show erroneously high vegetation cover.

Figure 4: A map showing fractional bare soil cover produced by the satellite-scale regression model from upscaled data. Field sites marked by dashed lines. Red arrows highlight errors produced by dark volcanic sands.

Results Continued

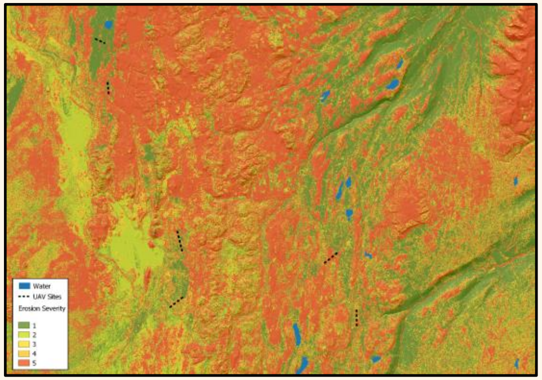


Figure 5: A map showing erosion severity derived from upscaled bare soil cover (Figure 4) and land monitoring data. Field sites marked by dashed lines.

- The erosion severity classification tends to highlight fine-scaled erosional features better than existing maps.
- The classification may exaggerate the area affected by severe erosion

Discussion

- These results show the potential for UAV data upscaling for monitoring soil erosion in Iceland.
  - Aligns with previous studies examining a similar approach for other environmental monitoring tasks[4-6].
- This approach may be adapted to extract other variables which may improve model specificity
  - Synthetic aperture radar may be used to upscale complex variables such as soil texture and vegetation structure[7,8].
- Applying this method to more field sites which capture the breadth of environmental conditions in Iceland may allow for a country-scale model to be developed.

Acknowledgments

Thank you to Dr. Noémie Boulanger-Lapointe for the valuable guidance, support, and opportunities she has provided throughout the tail end of my undergraduate degree. Thank you to Marteinn Möller for allowing me to join him in the field, making this work possible and for all his support while in Iceland. Thank you to the Soil Conservation of Iceland for providing data access. This research was supported by the Jamie Cassels Undergraduate Research Awards, University of Victoria, the Northern Scientific Training Program, Polar Knowledge Canada, the University of Iceland, and Resource International through In-Kind contributions.

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