Trail Erosion and Sustainability Analysis in the White Mountains of New Hampshire

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Introduction

Trail erosion is a critical challenge in maintaining the ecological integrity and accessibility of natural landscapes, particularly in high-use recreational areas like the White Mountains of New Hampshire. Known for their rugged terrain and beautiful vistas, the White Mountains attract more than 6 million annual visitors, intensifying the pressures on trail systems (USDA, 2023). Erosion, exacerbated by steep slopes, fragile soils, and increasingly severe weather events, not only diminishes the quality of trail infrastructure but also threatens surrounding ecosystems by altering hydrology, promoting sedimentation, and disrupting plant and animal habitats.

This project investigates erosion risk across the White Mountains trail network, focusing on the intersection of environmental factors and human activity. Employing Geographic Information Systems (GIS), this analysis integrates slope, soil erosion risk, precipitation, and trail use intensity to identify areas most vulnerable to erosion. The methodology will follow common approaches outlined in literature on erosion modeling, such as using DEM-based slope analysis and incorporating human activity data into geographic models of erosion risk. Studies like Eagleston and Marion (2020) and Kim and Daigle (2022) on utilizing GIS for trail sustainability will provide a framework for assessing conditions and identifying areas most in need of intervention. By leveraging publicly available data and trail popularity rankings, the study seeks to develop a composite risk index that highlights high-priority areas for conservation and maintenance efforts. Overall, this research aims to support the long-term preservation of the White Mountains' unique natural features while ensuring safe and enjoyable recreational opportunities for future generations.

Methods

To assess trail erosion risk in the White Mountain National Forest (WMNF), a series of geospatial analyses were performed utilizing GIS tools and publicly available datasets. The methods consisted of data acquisition, preprocessing, composite index calculation, and identifying high-risk trail sections.

1. *Data Collection and Preparation*
   Several datasets were sourced to evaluate erosion risk factors, including:
   - Precipitation data: Obtained from the National Oceanic and Atmospheric Administration (NOAA), representing 24-hour 100-year precipitation events.
   - Elevation data: Sourced from the United States Geological Survery (USGS) Digital Elevation Models (DEMs) to calculate slope.

- Erosion risk data: Data on potential erosion hazards from the gridded National Soil Survey Geographic Database (gNATSGO) was utilized to categorize erosion risk.
- Trail data: A curated list of the 20 most popular trails was created using trail rankings from AllTrails and trail network data from CalTopo.

Soil data were intended to be included in the analysis, but this dataset was unavailable for the WMNF area.

2. *Data Processing*
   Datasets were clipped to the spatial extent of the WMNF to ensure alignment and consistency. Additionally, trail data were refined to removed duplicates and each trail was assigned a popularity ranking based on AllTrails data. An Excel file containing trail names and popularity rankings was joined with the feature class to incorporate ranking.
3. *Composite Index Calculation*
   A composite erosion risk index was created by integrating trail use intensity, precipitation, slope, and soil erosion risk. This involved the following steps:
   1. The Zonal Statistics as Table tool was used to summarize the precipitation, slope, and soil erosion risk data for the top 20 trails in the WMNF.
   2. Then, the Calculate Composite Index tool was utilized to combine these variables into a single index layer.
4. *Identifying High-Risk Trail Sections*
   Trail segments were ranked based on their composite risk scores, and the top 3 trails with the highest erosion risk were identified as areas of concern. These high-priority areas were further examined to pinpoint the variables contributing most significantly to their erosion susceptibility and to identify the specific portions of the trails most vulnerable to damage.

Results

The analysis evaluated trail erosion risk across the 20 most popular trails in the White Mountain National Forest (WMNF) by integrating factors such as trail popularity, slope, and precipitation. Each trail was assigned a composite erosion risk index, facilitating the ranking of trails from highest to lowest erosion susceptibility (Appendix 1: Figure 1, Figure 2).

The top three trails with the highest erosion risk indices are:

1. **Mount Washington via Tuckerman Ravine and Lion Head Trail:** This is the 7th most popular trail, but has the highest risk of erosion due to its extremely steep slopes and high precipitation rates. The trail section in the ravine is highly vulnerable to erosion due to its steepness, with grades up to 65%.
2. **Mount Washington and Monroe via Ammonoosuc Ravine Trail**: This trail is the 9th most popular and suffers from large precipitation events due to the mountain's prominence. The trail also follows a large river (the Ammonoosuc River) for much of the trail, making it prone to erosion and flooding alongside it.

3. **Mount Pierce via Crawford Path**: This trail is more popular as the 5th most popular trail, and its high risk results from its steep slopes and moderate precipitation exposure.

Conversely, trails such as Diana's Baths and North and South Kinsman via Fishin' Jimmy Trail exhibited the lowest erosion risk indices, correlating with gentler slopes and lower precipitation exposure.

Conclusion and Recommendations

This analysis highlights the critical need for targeted trail management strategies in the White Mountains. Trails with high composite erosion risk, such as Tuckerman Ravine, Ammonoosuc Ravine, and Crawford Path, should be prioritized for conservation and maintenance efforts. While the most popular trails often receive the bulk of attention and funding, this study emphasizes the importance of focusing on trails that present a unique combination of high popularity and inherent environmental risk factors, such as steep slopes and exposure to heavy precipitation. Strategies may include implementing erosion control measures, such as switchbacks or water bars, and limiting access during periods of heavy rainfall to minimize further degradation (State of New Hampshire, 2017). Expanding this analysis to include additional data, such as soil composition and vegetation cover, could enhance the precision of future assessments. By addressing these challenges proactively, stakeholders can ensure the sustainability of the WMNF's trail systems, preserving its ecological integrity and recreational value for generations to come.

Appendix 1: Figures

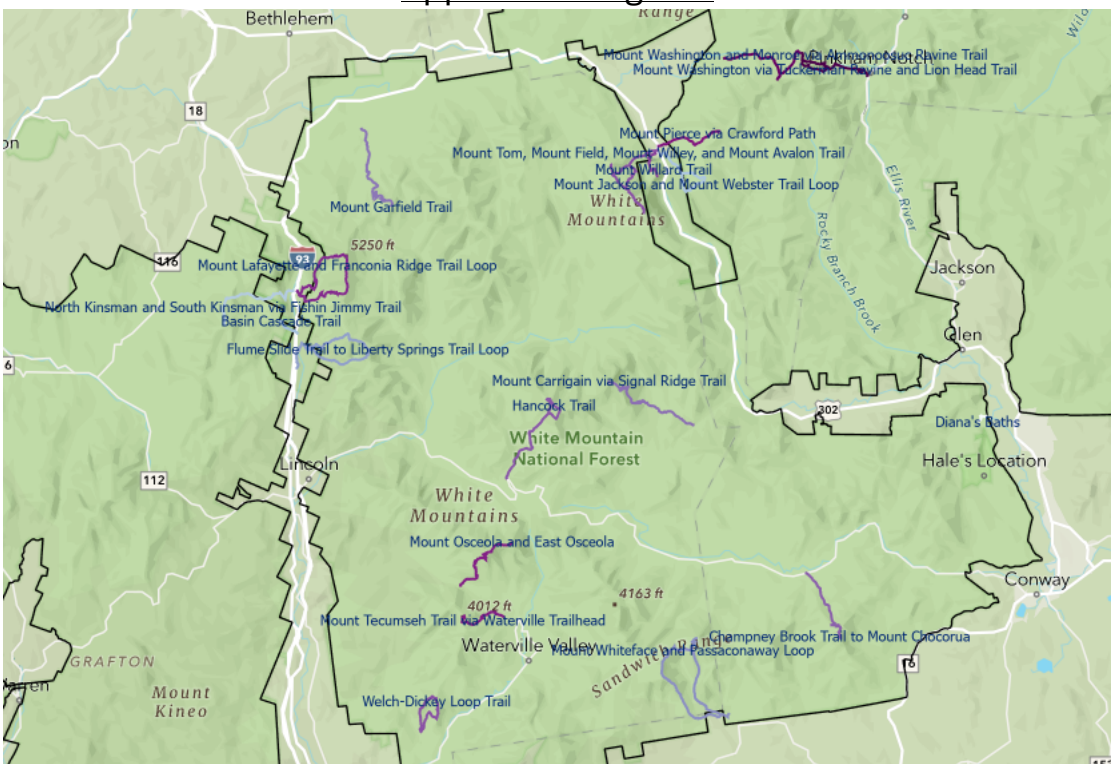

Figure 1. Top 20 most popular trails in the WMNF, colored by composite erosion risk index.

Trail Name	Popularity Ranking	Erosion Risk	Slope	Precipitation	Composite Index
Mount Washington via Tuckerman Ravine and Lion Head Trail	7	0.85	1.00	1.00	100.00
Mount Washington and Monroe via Ammonoosuc Ravine Trail	9	1.00	0.80	0.96	94.74
Mount Pierce via Crawford Path	5	1.00	0.77	0.59	89.47
Mount Tecumseh Trail via Waterville Trailhead	4	1.00	0.94	0.29	84.21
Mount Osceola and East Osceola	6	1.00	0.99	0.34	78.95
Mount Lafayette and Franconia Ridge Trail Loop	1	0.86	0.74	0.38	73.68
Mount Willard Trail	2	0.80	0.55	0.54	68.42
Welch-Dickey Loop Trail	3	0.98	0.69	0.12	63.16
Mount Tom, Mount Field, Mount Willey, and Mount Avalon Trail	12	1.00	0.68	0.56	57.89

Hancock Trail	10	1.00	0.67	0.42	52.63
Champney Brook Trail to Mount Chocorua	15	1.00	0.79	0.50	47.37
Mount Carrigain via Signal Ridge Trail	18	1.00	0.82	0.50	42.11
Mount Garfield Trail	11	1.00	0.66	0.23	36.84
Mount Whiteface and Passaconaway Loop	19	0.92	0.64	0.54	31.58
Flume Slide Trail to Liberty Springs Trail Loop	14	0.98	0.48	0.23	26.32
Basin Cascade Trail	16	1.00	0.32	0.15	21.05
Mt. Waumbek and Mt. Starr King via Starr King and Kilkenney Ridge Trail	8	0.52	0.53	0.00	15.79
Mount Jackson and Mount Webster Trail Loop	17	0.00	0.83	0.59	10.53
North Kinsman and South Kinsman via Fishin Jimmy Trail	20	0.99	0.28	0.23	5.26
Diana's Baths	13	0.04	0.00	0.25	0.00

Figure 2. Composite erosion risk index of top 20 most popular trails in the WMNF.

Appendix 2: Citations

References

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Appendix 3: Project Fulfillment

Data Set	Name	Description
1. Downloaded dataset.	100yr24h_precip_wmnf	Obtained from the National Oceanic and Atmospheric Administration (NOAA), representing 24-hour 100-year precipitation events.
2. Dataset made from scratch.	Top20Trails	A curated list of the 20 most popular trails was created using trail rankings from AllTrails and trail network data from CalTopo.
3. Joined table.	Top_20_Trails	A table containing trail names and popularity rankings, joined to the Top20Trails feature class.
4. Raster dataset.	100yr24h_precip_wmnf	Obtained from the National Oceanic and Atmospheric Administration (NOAA), representing 24-hour 100-year precipitation events.
5. Vector dataset.	Top20Trails	A curated list of the 20 most popular trails was created using trail rankings from AllTrails and trail network data from CalTopo.
6. Qualitative dataset.	ErosionRisk_wmnf	Data on potential erosion hazards from the gridded National Soil Survey Geographic Database (gNATSGO) utilized to categorize erosion risk.
7. Quantitative dataset.	100yr24h_precip_wmnf	Obtained from the National Oceanic and Atmospheric Administration (NOAA), representing 24-hour 100-year precipitation events.
8. Interpolated or calculated dataset.	TrailRiskIndex	A composite erosion risk index was created by integrating trail use intensity, precipitation, slope, and soil erosion risk.