Manual Clearcutting, Soil Permeability and Climate Dynamics: Assessing Environmental Impact in Black Rock Forest, NY

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Introduction

- Clear-cutting[1] is a system that removes an entire stand of trees in a single harvesting operation. Also damaging is forest degradation[2], which is the loss or reduction of a forest's ecosystem through intensive logging. Soil degradation, driven by manual deforestation impacts both local ecosystems and global environmental health. Degradation and deforestation is the second-largest source of global carbon emissions, after the burning of fossil fuels[3]. This issue is relevant in many areas like Black Rock Forest in New York, a living laboratory for field-based research and education, which has experienced two centuries worth of logging, farming and fire disturbances[4].
- Manual deforestation directly leads to soil erosion, reduced water retention, and a decline in biodiversity. Locally, NY has experienced a 2.2% decrease in tree cover from 2000 to 2023[5]. Globally, manual deforestation is a primary driver of soil degradation. In the Brazilian Cerrado, the conversion of native vegetation to pasture and cropland has led to severe soil erosion and decreased infiltration rates[6]. One study in the Cerrado found an "impermeable water table" at 14cm deep due to anthropogenic land use, with overland flow saturation and excess infiltration during heavy rainfall[7], causing soil structure disruption. This loss of vegetation and the disruption of the soil's natural processes results in long-term degradation that can take decades to recover.

Connection of Environmental Issue to Research Question

- Permeability refers to the idea that the more permeable the soil, the greater the seepage. It is the property of the soil to transmit water and air[8]. Permeability is reliant on the type of soil[9], with clay being the most porous sediment but the least permeable, and gravel and sand being both porous and permeable, with gravel having the highest permeability[10]. The shape/texture of soil particles, the relative volume of voids in the soil (voids ratio), compaction, and the saturation degree all influence permeability[11].
- Deforestation alters the porosity of the soil through the hydrologic cycle, which affects infiltration and transpiration of soil nutrients, ultimately affecting soil permeability[12]. The absence of tree roots and organic matter in deforested areas often increases compaction and reduces the soil's ability to retain water and nutrients, like nitrogen and phosphorus, that are crucial to fertility[13]. These changes directly affect soil permeability, a key indicator of hydrological function, as water moves differently through degraded soil, leading to erosion and loss of topsoil[14]. This study focuses on Black Rock Forest, NY, where areas impacted by manual clearcutting in 2022 provide a critical opportunity to investigate how deforestation influences soil permeability compared to intact forested regions.

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Research Question

RQ: How does soil degradation caused by manual clearcutting performed in 2022 affect the rate of soil permeability (m/s) compared to forested areas today in Black Rock Forest, New York?

Hypothesis: Soil percolation rate (m/s) in recently deforested areas will be slower than in forested areas due to reduced organic matter and compaction.

Sample #	Location	Time (s)
1	Location C	55.63
2	Location C	39.54
3	Location C	44.43
4	Location C	42.00
5	Location C	115.83
6	Location E	171.34
7	Location E	64.54
8	Location E	94.00
9	Location E	112.45
10	Location E	62.32

Figure 1: Raw data for locations C and E. Location C is the Forested Area, or the Control Sample, and Location E is the Deforested Area, or the Experimental Sample.

Processed Data for Location v Time (s)

4A

LOCATION	Mean of Time (s)	Standard deviation
Location C	59.486	32.093
Location E	100.93	44.591

4B

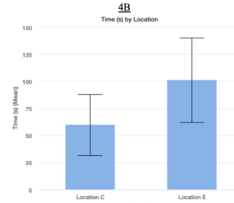

Figure 2: Processed data showing the mean time (in seconds) per location (4A), with bar graph demonstrating the numbers in graphical form (4B). Standard deviation is represented as error bars above.

Methods

I obtained a permit for soil collection and followed the state paths.

- Soil samples collected at 15 cm depth from forested (control) and clearcut (experimental) sites.
- Step on the pedal of the soil probe and insert it 15 cm deep into the soil.
- Push down to collect 15 cm of soil from each of 5 locations in the deforested area and 5 locations in the forested area. This will ensure that approximately 100 mL of soil is collected from each site.
- Put soil into a plastic bag, seal, and store in garage until ready to do lab test.

Repeat steps below for 5 trials using soil from both deforested and forested areas:

- Fold a circular piece of filter paper in half, then fold it again to form a cone.
- Place cone in funnel.
- Position the funnel with the filter paper in a 250 mL graduated cylinder.
- Fill the filter paper with the collected soil sample, stopping 1 cm from the top.
- Prepare a stopwatch to time the filtration process.
- Slowly pour tap water into the funnel until you collect a measurable amount (e.g., 20 mL) in the graduated cylinder.
- Record the amount of water in beaker and time taken to reach it.
- Calculate the percolation rate (mL/s) by dividing the recorded water volume (mL) by the time elapsed (seconds).

Statistical analysis: Mann-Whitney U test.

Preliminary Findings and Insights

Dependent variable	Value	Count	Mean	Median	Standard deviation	Standard error of the mean
Time (s)	Location C	5	59.486	44.43	32.093	14.352
Time (s)	Location E	5	100.93	94	44.591	19.941

Mann-Whitney *U* test (independent samples)

U value	*P* value
4	0.0947

This investigation observed the impact of manual clearcutting on soil permeability by comparing water percolation time in a forested area (Location C) and a deforested area (Location E).
The Mann-Whitney *U* Test ($p = 0.0947$) showed no statistically significant difference in mean percolation time between the two locations (59.49 seconds in Location C and 100.93 seconds in Location E). While this indicates a trend towards slower percolation in Location E, the large standard deviations (32.093 seconds in Location C and 44.591 seconds in Location E) indicate variation in percolation times between both locations.

Discussion:

Clearcutting appears to slow infiltration, suggesting soil compaction and loss of organic matter.

- Although no statistically significant difference was found, the observed numerical trend highlights a possible trajectory toward long-term soil degradation.
- Observed soil in clearcut site was compacted and bubbly (possible CO_2 release).
- Limitations: sample size, soil type variability, lab-based not field-based measurements.

Conclusion:

Clearcutting in Black Rock Forest shows a trend towards slower soil permeability, indicating potential long-term soil degradation, though it was not statistically significant.

Applications:

- Mulching with organic matter could restore soil structure.
- Community-based restoration pilot projects are recommended to prevent long-term soil degradation.

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* At the time of this study, Michelle Rozenfeld was a high school senior at Bergen County Academies, Hackensack, NJ. This work was originally presented at CANVAS 2025 Conference, Salt Lake City, UT