Dendrochronology and the Mile 11 Landslide in Wrangell, Alaska

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Introduction

On November 20, 2023, a deadly landslide swept across the Zimovia Highway southwest of Wrangell, Alaska. The landslide claimed the lives of six individuals and caused extensive property damage along its path. I was approached by my mentor, Dr. Margaret Darrow, with an idea for research in relation to the landslide. Wrangell, Alaska is surrounded by the Tongass National Forest. This rainforest boasts some of the largest trees in the country. When the landslide occurred, the storm was accompanied by high winds, which led to the questions: "Did the trees trigger the landslide? Are the trees that came down in the landslide able to provide hints of slope instability prior to the landslide event?" To answer these questions, I split my project into two different parts: (1) using ArcGIS Pro to produce a change detection map of the digital surface model (DSM); and (2) determining the age of trees caught within the landslide to understand more about their role in the landslide occurrence.

Methodology

• Tree Cookie Analysis

1. Cut slabs (cookies) off downed Western Hemlock trees in Wrangell using a chainsaw.
2. Dry samples.
3. Sand rings using 50, 120, 150, 220, and 400 grit sandpaper with a belt sander and a palm sander.
4. Scan samples using a high resolution scanner.
5. Count tree cookies rings by hand and note any anomalies.

• Change Detection Analysis

1. Download data.
2. Import the pre-slide and post-slide lidar data into Arc GIS Pro.
3. Clip data into useable blocks.
4. Apply the hill shade tool to reveal terrain features.
5. Use the "Change Detection Wizard" tool to show the difference between the pre-slide and post-slide LiDAR data.
6. Use the LiDAR data to count the number of downed trees removed by the landslide.
7. Assign symbology to the new change detection map.
8. Compare the difference in elevation from the slide path to the tops of adjacent trees to determine tree height.

Figure 1. (a) An unsanded tree cookie. (b) A sawyer preparing to cut a cookie. (c) Sanding the tree cookies. Photo credits: (a) J. Fields, (b) M. Darrow, (c) J. Davis

Results and Analysis

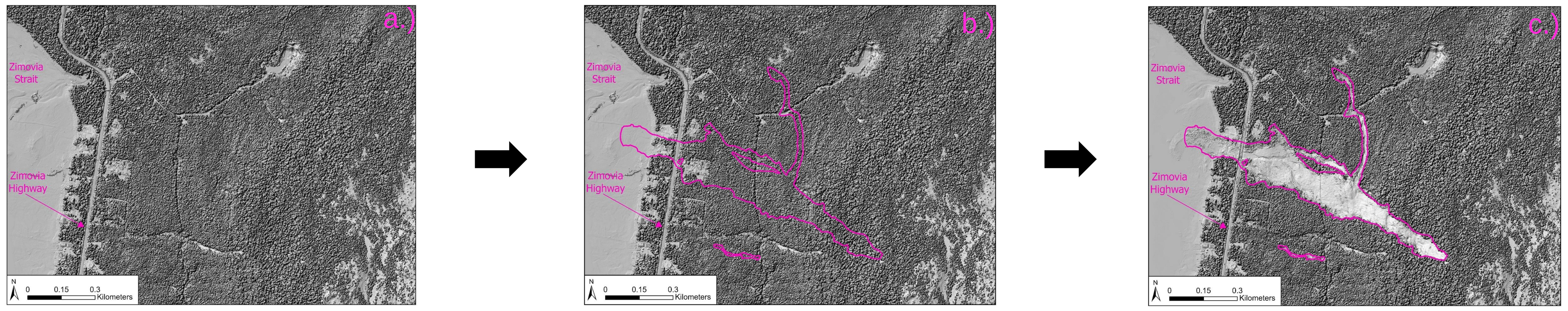

Figure 2 (a) LiDAR showing mile 11 of the Zimovia Highway prior to the landslide. (b) LiDAR showing area of the landslide prior to sliding with the outline of the landslide in magenta. (c) Post landslide LiDAR showing the landslide in magenta.

Change Detection Analysis

After differencing the digital surface model (DSM) LiDAR, Figure 3a, the goal was to obtain as much information as possible about the trees in the landslide's path (outlined in magenta in Figures 2 and 3a). Fortunately, LiDAR was collected by the Alaska Division of Geological and Geophysical Surveys (DGGS; Zechmann et al. 2023,2024) prior to the landslide event. This allowed me to estimate the number of fallen trees in the landslide's path, determine how tall the trees are adjacent to the landslide, calculate the landslide's area, and understand the surficial difference throughout the entire landslide. Counting by hand, I estimate that about 2,000 trees were downed in the Mile-11 Landslide. The DSM differencing indicates that the surface went down as much as 59 meters (dark purple). I masked the DSM of difference (Figure 3a) to hide areas that seem to be from error in the LiDAR collection (seen in white on the legend). The rise is most likely due to vegetation accumulation near the bottom of the landslide. The total area of the landslide equals 178,608 square meters or about sixteen soccer fields arranged side-by-side.

Tree Cookie Analysis

The tree cookies that were sampled were Western Hemlock native to the Tongass. Because these tree cookies came from trees where the bottom 10-15 ft were missing, I added 20 years to each tree to be conservative. The youngest sample (Figure 3b), was 292±10 years old, followed by 306±10, 307±10, and 322±10 years old. These ages indicate that these trees were part of the old growth forest and not impacted by logging operations in the 20th century. Several environmental impacts can be seen on each sample including reaction wood, heart rot, ambrosia beetle burrow trails, branch growth marks, and fluting. Reaction wood, an indication of slope movement and tree readjustment, is present in all four trees. Periods of growth cycles are observed showing times of growth stagnation and regeneration.

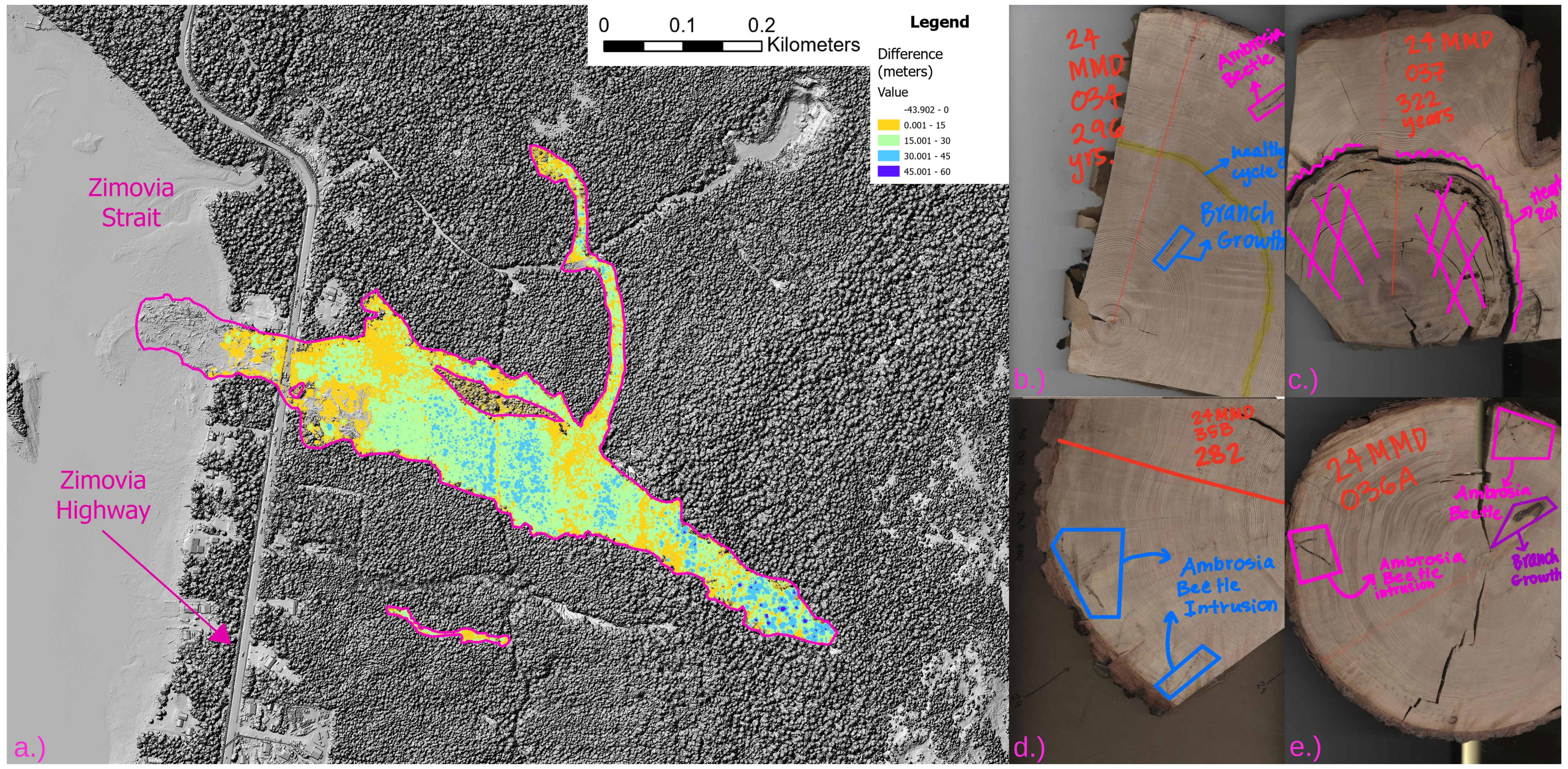

Figure 3. Change detection and tree ring analysis results: (a) change detection map showing landslide area and difference in LiDAR elevation (in meters) withing the landslide; (b) cookie 24MMD-034 showing branch growth distortions, Ambrosia beetle burrowing, and ring count total;- (c) cookie 24MMD-037 showing heart rot, tree fluting, and age; (d) cookie 24MMD35B showing Ambrosia beetle burrowing; (e) cookie 24MMD-036A showing Ambrosia beetle burrowing and branch growth. Photo credits: J. Fields

Conclusions

Tree Cookie Analysis

The tree cookies indicate that there were several environmental changes throughout the lives of the trees. Each cookie had features in common, such as ambrosia beetle burrowing, branch growth marks, and ring width variances. Reaction wood was observed on sample 24MMD-36A (Figure 3e), however, it only appeared for a few years in the tree's lifespan and reaction wood was not consistently seen in other samples, which I would expect if there was any slope movement prior to the landslide.

Because the LiDAR differencing revealed a surficial difference of up to 59 meters, these trees were untouched by logging operations. Next, on the far right part of the landslide, the head scarp begins about 300 meters upslope into the old growth forest. The trees I sanded appeared healthy with minor environmental strains throughout each lifespan except for sample 37 (Figure 3c). There is significant heart rot fungus, which requires an ample supply of water with a humid environment.

Entomology

Throughout Southeast Alaska the blackheaded budworm and the hemlock sawfly have steadily migrated north from the Pacific Northwest favoring the humid climate and warmer temperatures. Their symbiotic relationship has caused disease within trees in the Tongass for several years, making trees appear dead as the tree directs its nutrients inward to survive. The cookies processed showed no signs of their habitation and the paths carved into the trees in Figures 3b, 3d, and 3e were from the Ambrosia beetle. These marks were carved after the tree had been killed and is a natural decomposition process.

Recommendations

Although there are still many unanswered questions regarding the Mile 11 Landslide, there is no direct evidence indicating that the trees themselves were the sole reason for the landslide. These results suggest that the trees were most likely healthy when the landslide occurred. The storm that swept through Wrangell on the eve of the landslide brought high winds and some precipitation. Future work could include meteorological analyses, soil property investigations, and historical logging operations studies.

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