Using COSI-Corr to Quantify Earthflow Movement Rates Over Decadal Time Scales

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MOTIVATION

Large, complex earthflow systems can evolve seasonally to millennially. In many areas, extensive archives of historical aerial photographs offer potential for quantifying decadal fluctuations, but tracking individual features has been impractical over significant temporal and spatial scales.

INTRODUCTION

- COSI-CORR

  The Co-registration of Optically Sensed Images and Correlation (COSI-Corr) software module uses the ENVI interface to orthorectify, co-register, correlate, and track surface deformation between images. Here COSI-Corr correlates air photographs and LiDAR imagery to look for earthflow movement between each successive time step.

- WHY WAIPAOA RIVER (NZ)?

  The upland hillslopes of the Waipaoa River (fig. 1) catchment are currently adjusting to rapid base level fall following the Last Glacial Maximum. The active earthflow response to channel incision makes exploring the feasibility of COSI-Corr over decadal time periods possible.

WAIPAOA RIVER CATCHMENT

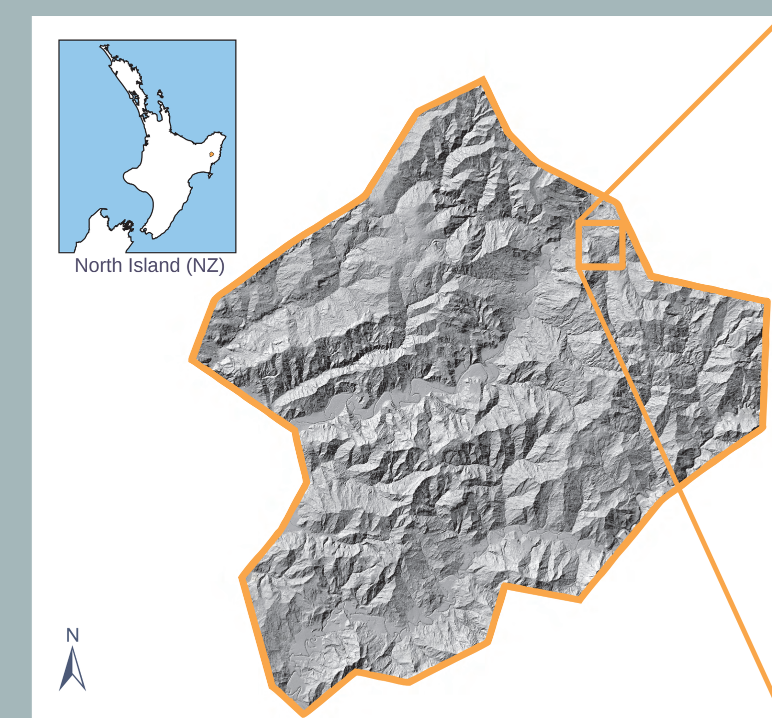
To analyze the efficacy of COSI-Corr for landslides, we used a 1 km^2 area in the upper Waipaoa (part of a larger study site).

- GEOLOGY

  Late Cretaceous-Early Tertiary clay-rich mudstones and calcite-rich sandstones with highly sheared and more massive units that fail in diverse fashion.
- LAND-USE

  In the 1900s, the area was burned and converted to pastureland. Currently it is heavily grazed by livestock.
- MOVEMENT

  Slopes deformation occurred in the past, but has accelerated due to land use changes. By 1982, the areas of highest erosion were replanted.



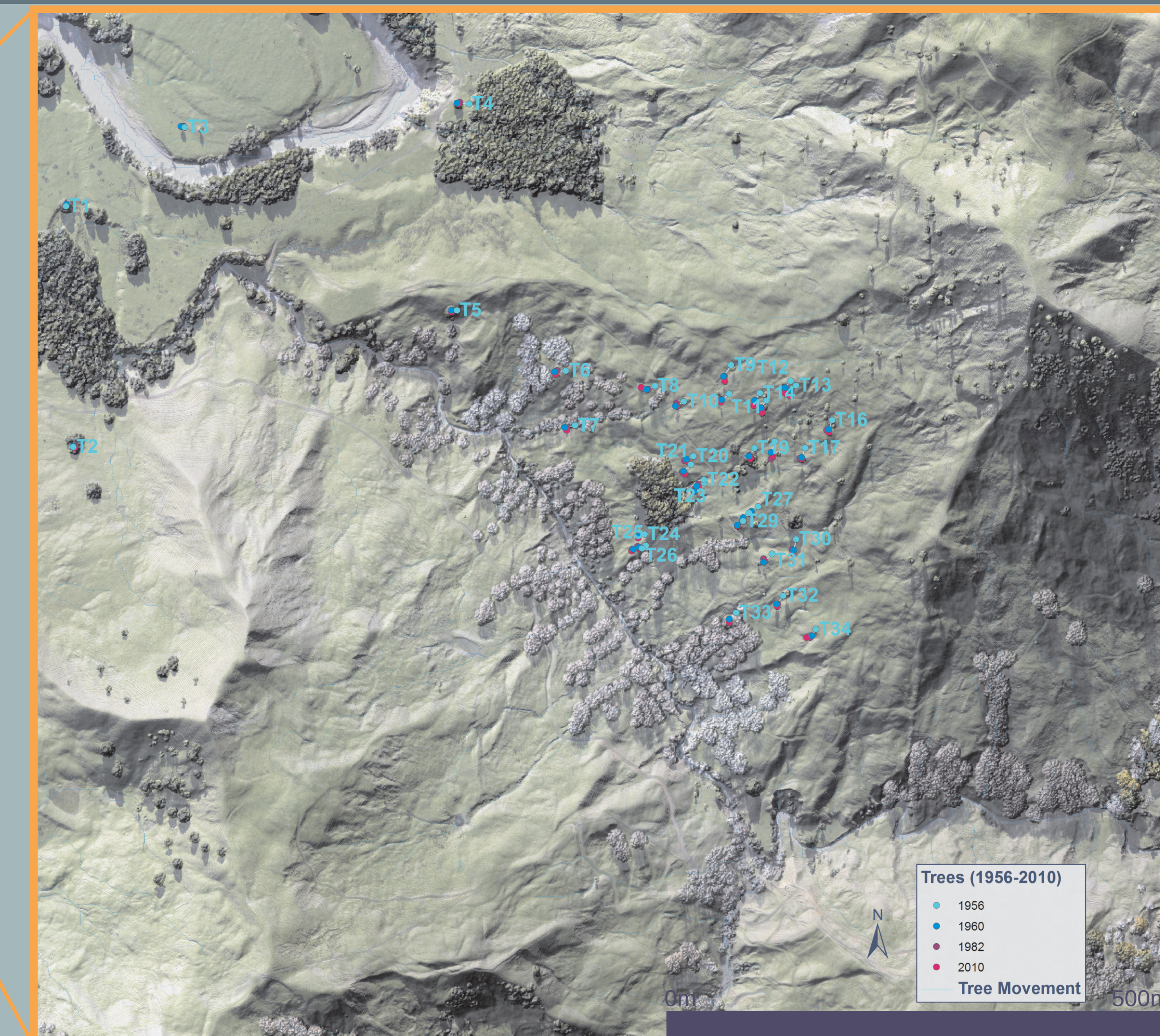


Fig. 1a: (above) The area for this study is a subset of the above 169 sq. km LiDAR survey of the Waingaromia and Waihora Rivers (tributaries to the Waipaoa River) on the North Island, NZ.

Fig. 1b: (right) The 2010 orthophoto and LiDAR hillshade image is marked with the location of the 34 trees from 1956 to 2010. Tree movement, shown with teal lines, is generally downslope. Some trees track uphill or across slope, likely due to rectification errors.

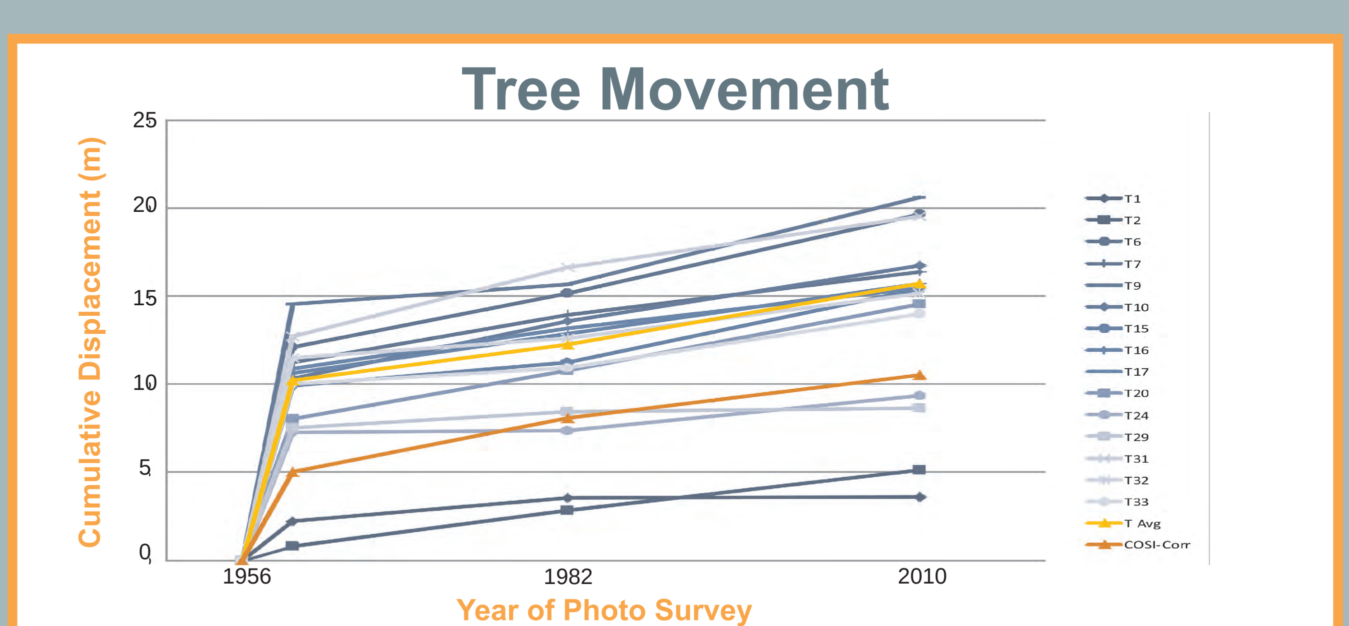


Fig. 2: Trees were tracked manually using LiDAR and air photos from 1956 to 2010. Of the 34 tracked trees, 15 are shown here. T1-T5 are stable points, and approximate the error in selection and rectification. T6-34 are located on the active slopes to the east of the channel. The velocity for the trees (yellow line) is 2.6m/yr, 0.1m/yr, and 0.9m/yr for each progressive time step. The COSI-Corr velocities (orange line) follow the same trend, but average 1.3m/yr, 0.2m/yr, and 0.1m/yr.

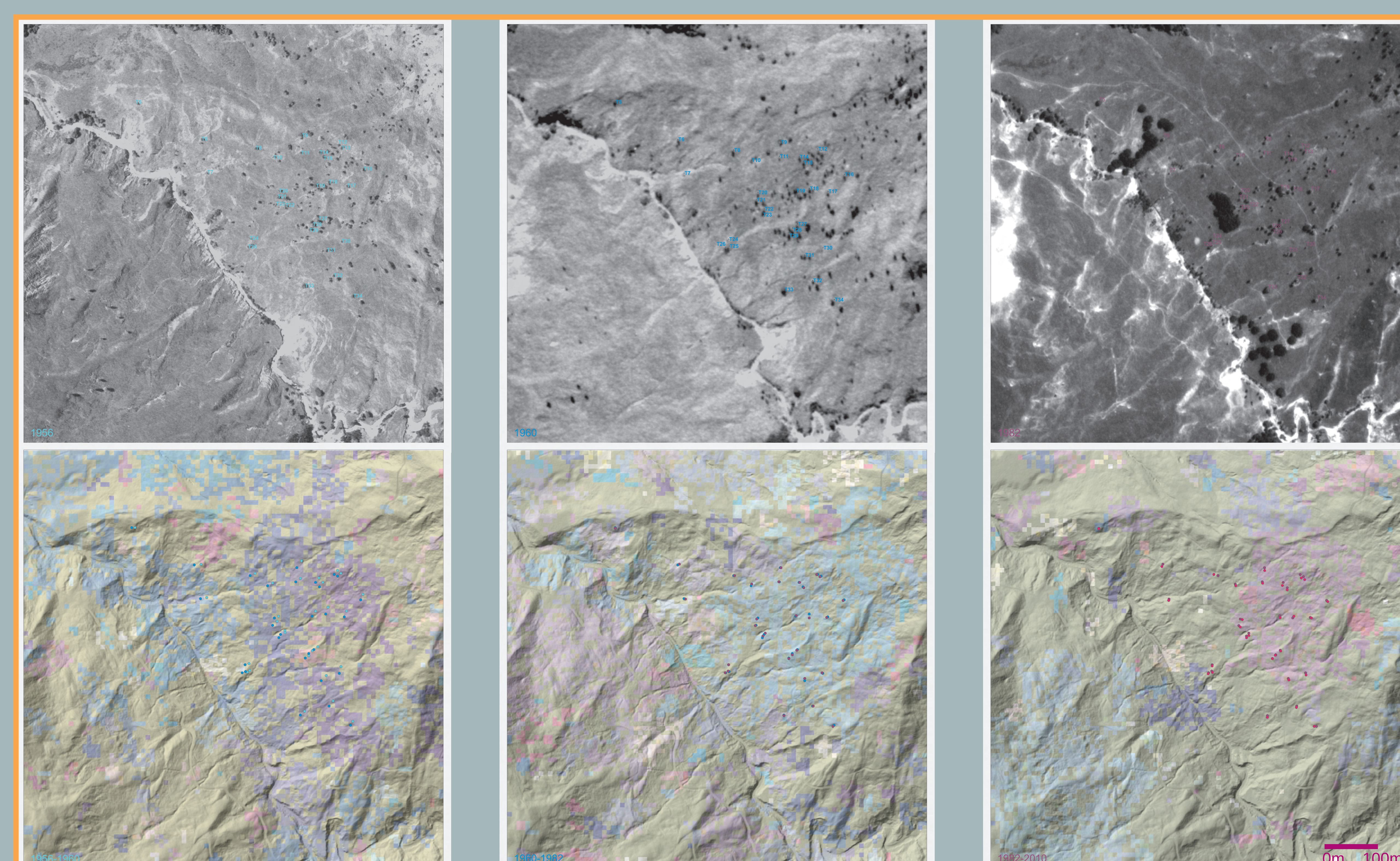


Fig. 3: The top row are orthorectified aerial photographs (1956, 1960, & 1982). The 2010 orthophoto is included in fig. 1. The manually tracked trees are marked as T1-T34. The bottom row shows the COSI-Corr results for each time step (1956-1960, 1960-1982, & 1982-2010) centered at the same location. The results are filtered to eliminate displacements>20m and SNR<0.9. The green color indicates no movement or a null value. COSI-Corr shows areas of deformation that correspond roughly with moving trees, but also locations of rapid failures, vegetation growth, and misregistration.

METHODS

- ORTHORECTIFICATION

  Three surveys (1956, 1960, and 1982), ranging from 1:17,400 to 1:44500 scale, were scanned at 1200 dpi (21 micron) resolution resulting in a ground resolution of 0.2-1m/pixel. The scans were imported into ENVI 4.5 and orthorectified using the COSI-Corr interface. Ground control points (GCP) were selected between each photo and the 2010 LiDAR hillshade. Initially optimization of the GCPs was attempted to generate better co-registration, but error was larger than manual point selection. Orthorectification was completed using the camera calibration reports and 2010 1m DEM. The photos were resampled using dx=dy=2.2 pixels and kernel=25 pixels.

- TREE TRACKING

  Rectified photos were imported into ArcGIS 10.0 and a set of 34 trees were selected to track. Of those, 29 trees spanned the active slope and 5 trees were on stable ground.

- CORRELATION

  The COSI-Corr frequency correlator tool was used to compare sequential time steps. The initial search window (x=y=256 pixels), final search window (x=y=32 pixels), and step (x=y=8 pixels) were set manually. The correlations were then filtered to eliminate noise (SNR<0.9) and large displacements (±20 m).

DISCUSSION AND RESULTS

- Poor rectification and poor image quality has led to large errors in tree tracking (both manually and with COSI-Corr)
- Misregistration persists in the photos, leading to orthorectification errors ranging from 1-15m
- GCP selection and manual tree selection errors range from 1-5m
- Rectification and correlation are problematic in areas of steep topography, areas of major vegetation change, and poor initial image quality.
- COSI-Corr determines movement where tree tracking showed movement, as well as areas where there was rapid failure and/or areas of newly planted vegetation
- Average velocity generally decreases (2.5m/yr to 0.9m/yr for the trees, and 1.3m/yr to 0.1m/yr for the whole slope)

CONCLUSION

- COSI-Corr can recognize deformation of earthflow-scale features
- COSI-Corr results can be filtered to pick out active areas in this study site
- Misregistration leads to large errors in manual tree tracking and correlations
- Without better orthorectification, displacement cannot be calculated confidently
- Need higher quality imagery and/or areas with more distinct textural differences and stable points in order to improve results

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