DYNAMICS OF THE RAPID TOPOGRAPHIC CHANGES AFTER RECENT MORAINE BREACH: A CASE STUDY OF THE DJANKUAT CATCHMENT, CENTRAL CAUCASUS

01. Introduction

- Instability in proglacial areas is often expressed in the high occurrence of intensive surface processes.
- The moraine collapse is one of the most severe events that lead to significant surface changes in the valley. Usually, the moraine breach is initiated by a combination of factors: ice dynamics, intense rainfall or snowmelt, seismic activity, and landslides.
- In the Caucasian region moraine failures were frequently reported. The goal of this study is to quantify the terrain transformation due to the moraine breach over a period of several years after the formation, and to evaluate the input of sediments into the SY.

02. Study site

- The Djankuat River catchment (43.20 N, 42.74 E).
- 27% of the catchment area (out of 9.1 km²) is glaciated; all glaciers experience negative dynamics.
- Typical alpine terrain. Dominant elements are lateral moraines formed during the LIA. Their height is up to 50 - 55 m.
- On the right side of the valley is a large glacial cirque Koiavgan (total catchment area 3.03 km², cirque is 0.6 km²). Here starts the left tributary, which breaches the moraine downstream.
- This section of the lateral moraine collapsed on 1st July 2015 and the Koiavgan Creek redirected its course.

03. Methodology

03.01 Moraine gullies

Very sensitive to DEMs co-registration errors

Another approach required

- Stable surfaces near the drainage divide and the gullies
- Active erosion at the talweg zone and at the banks

03.02 Breach area

Source: high-resolution satellite images and UAV surveys Images: 2010, 2017 (1 m res.
- DEMs, stereo imagery); 2019, 2021, and 2022 DEMs from UAV surveys (0.063 - 0.089 m res.)

Volume and average depth calculation for every gully (out of 21). Through the construction of baseline surfaces obtained via interpolation (Delaunay triangulation), Cathlins’ borders for every DEM.

Drainage divides height change significance:
1) Wilcoxon rank test;
2) Height distribution via the Pearson chi-square method.

03.03 Snow cover and hydrometeorology

Snow cover
Source: 1-day MODIS NDSI
Methodology: 1) two zones (downstream and upstream sectors); 2) detection of abrupt changes (melting start) via the Pettitt test;

Hydrometeorology
Ablation seasons 2007-2022
- Water discharge
- Daily mean air temperature
- Daily rainfall sums
- Suspended sediment concentration

04. Results

04.01 Breach area

Annual changes
Change in surface area, m²
Deposition:
Eroded

04.02 Moraine gullies

For the gullies on the right side from the breach (18) there is a clear erosional trend. Gullies closer upper in the valley experienced more deepening. In total, 10.2 m³ eroded for a 12-year interval (921 m³ per year).
- Only 1-5 volume changes per interval were not significant.
- For three gullies on the left side (down the breach), there is no clear erosional trend. Initially (2010-2017) it was deepening. Followed by stabilization and deposition. More dependent on the breach formation.

05. Discussion

Snow cover. The year 2015 is exceptional as the melting started in the entire basin on the same date, while for other years on average, 10 days delay was typical.

Exceedance probability (SSL). Five events (2015-2021) with the AEP <10%: three in 2015, one in 2017, and 2018. The breach was formed during the event of 0.1% AEP (1000 years).


06. Conclusion

- The breach formation and the following terrain development are caused by extreme meteorological events (high precipitation and air temperature).
- The volumetric assessment accuracy of the breach terrain change detection is dependent on the position of ground control points.
- The sediments entering Djankuat River due to the breach and Koiavgan Creek (downstream) erosion contribute to at least 50% of the total SY for particular years.
Dynamics of the rapid topographic changes after recent moraine breach: a case study of the Djankuatu catchment, Central Caucasus

Kedich et.al, 2023

Supplementary Materials

Methodology

Figure 1 — Hydrometeorological data availability for the 2007-2022 period at DGS.

Results

Figure 2 — 1. cross-sectional profile through the breach; 2. Longitudinal profile created from averages from the series of cross-sectional profiles per every meter along the creek valley bottom
Figure 3 — Koiavgan Creek longitudinal profile (based on cross-sectional profiles of the creek valley bottom drawn per every meter); Creek cut cross-sectional profile G-H

Figure 4 — Breach cross-sectional profile E-H
Figure 5 — Gullies' depth development to the right side of the breach (down the main Djankuat valley); Mean ± SD

Figure 6 — Timeseries of the changing NDSI pattern during the 2007-2022 period. NDSI values were retrieved from MODIS products and further smoothed using a Savitzky-Golay weighting filter.
Table 1. Event-based suspended sediment loads (t/event) at the DGS for the period 2015–2021.

<table>
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<tr>
<th>Year</th>
<th>n</th>
<th>range</th>
<th>Total</th>
<th>Mean</th>
<th>SD</th>
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<td>159</td>
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<td>9500</td>
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<td>170</td>
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<td>1800</td>
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<td>5138</td>
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<td>145</td>
<td>06 Jun - 21 Sep</td>
<td>3161</td>
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Table 2. Most extreme hydrological events in terms of suspended sediment export (with AEP < 10%) during the 2015-2021 period.

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<th>End</th>
<th>Duration, hour</th>
<th>( Q_{\text{mean}} ), m³/s</th>
<th>( Q_{\text{max}} ), m³/s</th>
<th>( \text{SSC}_{\text{mean}} ), g/m³</th>
<th>SSL, t/event</th>
<th>AEP</th>
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Figure 7 — Annual exceedance probabilities of five annual maximum hydrological events in terms of SSL for 2015-2021 period.