After The 2017 Disaster: Villa Santa Lucia And Its Surrounding Glaciers. A Contribution To Resilience From A Glaciological View At Chilean Northern Patagonia.

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Abstract

On 16 December 2017 a chain mass movement, started as a rockslide, produced a debris and mud flow which channelized in the Burritos River. The flow reached and flooded the Santa Lucia village (-43.41°/-72.37°) destroying 50% of the urban area and killing 22 people. This fatal event resulted as a conjunction of geologic, meteorological and glaciological variables: Highly altered volcanic rocks with deep vertical fractures and steep slopes in the Yelcho Range; an intense precipitation event 30 hours prior the rockslide of up to 124.8 mm in one day with a high zero-degree isotherm elevation; an ice-cored lateral moraine deposit under the headwall plus hyper saturated soils downhill near the Burritos River. The role of a proglacial lake has been discussed, nonetheless, current studies argue that the main liquid inputs could have been pre-existing water in saturated soil. In this study we analyzed satellite imagery available on the web, including Sentinel 2 and Landsat scenes. Based on the Public Chilean Glacier Inventory, we quantify the retreat of glaciers laying on the eastern flank of the Yelcho Range, west of the Santa Lucía village. On a time-span of 33 years (1987 to 2020), we estimate over 650 m of glacial retreat plus an accelerated retreat rate up to 30 m/yr for the last decade. Such glacier shrinkage coupled with increasing local temperatures may lead to the genesis of more proglacial lakes, enhancing the odds of chain mass movements, favoring the interaction between rockslides and glacial lakes. Our results show an example of a relatively simple analysis that can be performed with basic tools and with no further expenses. The proper understanding of glacial landscape evolution with time and its response to extreme climatic events is essential to prevent human loses, as these events will be more frequent due to the current climate change context. For that purpose, further work aims to clarify more hidden variables in the region, such as the number of proglacial lakes, steep slopes on headwalls, highly eroded slopes, among others, in order to enlarge the local knowledge linked to one of many components involved on a natural disaster, thus, increasing the resilience of communities whom are still occupying the affected area after the Santa Lucía landslide disaster.

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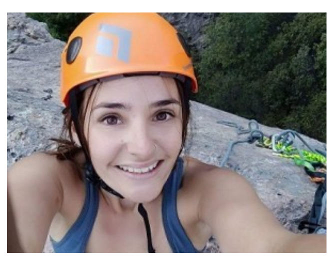

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ABSTRACT

On 16 December 2017 a chain mass movement, started as a rockslide, produced a debris and mud flow which channelized in the Burritos River. The flow reached and flooded the Santa Lucia village (-43.41°/-72.37°) destroying 50% of the urban area and killing 22 people. This fatal event resulted as a conjunction of geologic, meteorological and glaciological variables: Highly altered volcanic rocks with deep vertical fractures and steep slopes in the Yelcho Range; an intense precipitation event 30 hours prior the rockslide of up to 124.8 mm in one day with a high zero-degree isotherm elevation; an ice-cored lateral moraine deposit under the headwall plus hyper saturated soils downhill near the Burritos River. The role of a proglacial lake has been discussed, nonetheless, current studies argue that the main liquid inputs could have been pre-existing water in saturated soil.

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BACKGROUND

On 16 December 2017, a massive debris-flow triggered after a complex mass movement involving volcanic rocks, snow, heavy rain and glacial ice from one of the many Yelcho range glaciers (Figure 1).

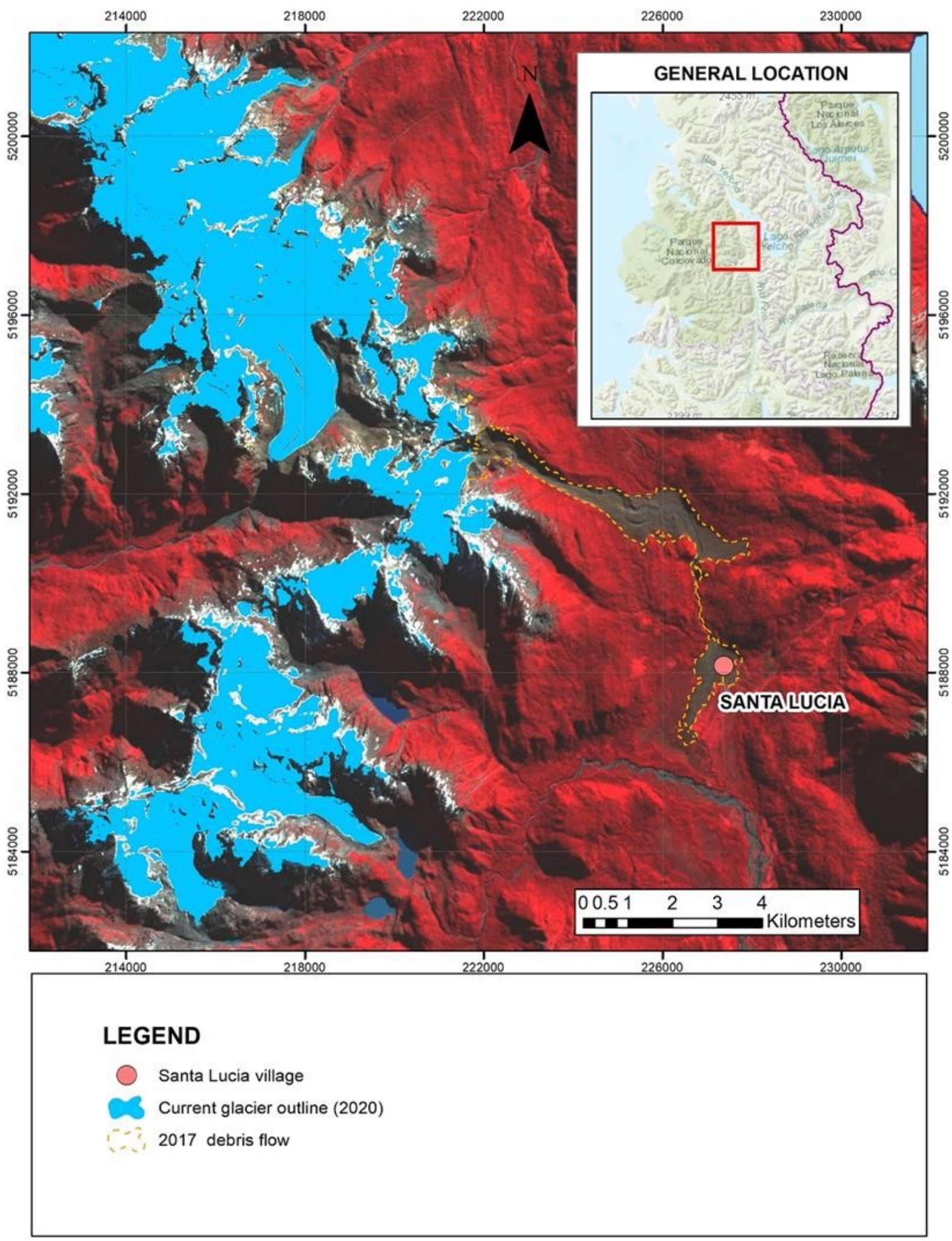

Figure 1: Location of the Villa Santa Lucía debris-flow deposit and its surrounding glaciers at the Yelcho range.

The flow reached and flooded the Santa Lucia village (-43.41°/-72.37°) destroying 50% of the urban area and killing 22 people. A mixture of sediment, ice, water and trees deposited covering an area of 9 x 10^5 m^2 (Somos-Valenzuela *et al*., 2020), Figure 2.

Half a year after the event, families insisted on returning (https://youtu.be/Qlz0LOBU6eE) to they home place at the Villa, regardless the posing risk.

Video: flight over the mud-flow deposit. Courtesy of TVD Patagonia PRENSA Digital

Materials

We used 4 Landsat images (Table 1) desplayed as color-infrared (CIR). A supervised classification was performed through GIS software in order to delimitate glaciers and proglacial lakes. A Digital Elevation Model, DEM, obtained from the ALOS PalSAR mission, was employed for mapping and topographical analysis.

Table 1: Images employed for mapping and classification process

Image	Satellite/Sensor	Adquisition Date	Spatial Resolution
LT05_L1TP_232090_19870124_20170215_01_T1	Landsat TM	1987/01/24	30
LE07_L1TP_232090_20000221_20170213_01_T1	Landsat ETM	2000/02/21	15
LE07_L1TP_232090_20100216_20161215_01_T1	Landsat ETM	2010/02/16	15
LC08_L1TP_232090_20200408_20200822_02_T1	Landsat OLI	2020/04/08	15

GLACIER RETREAT

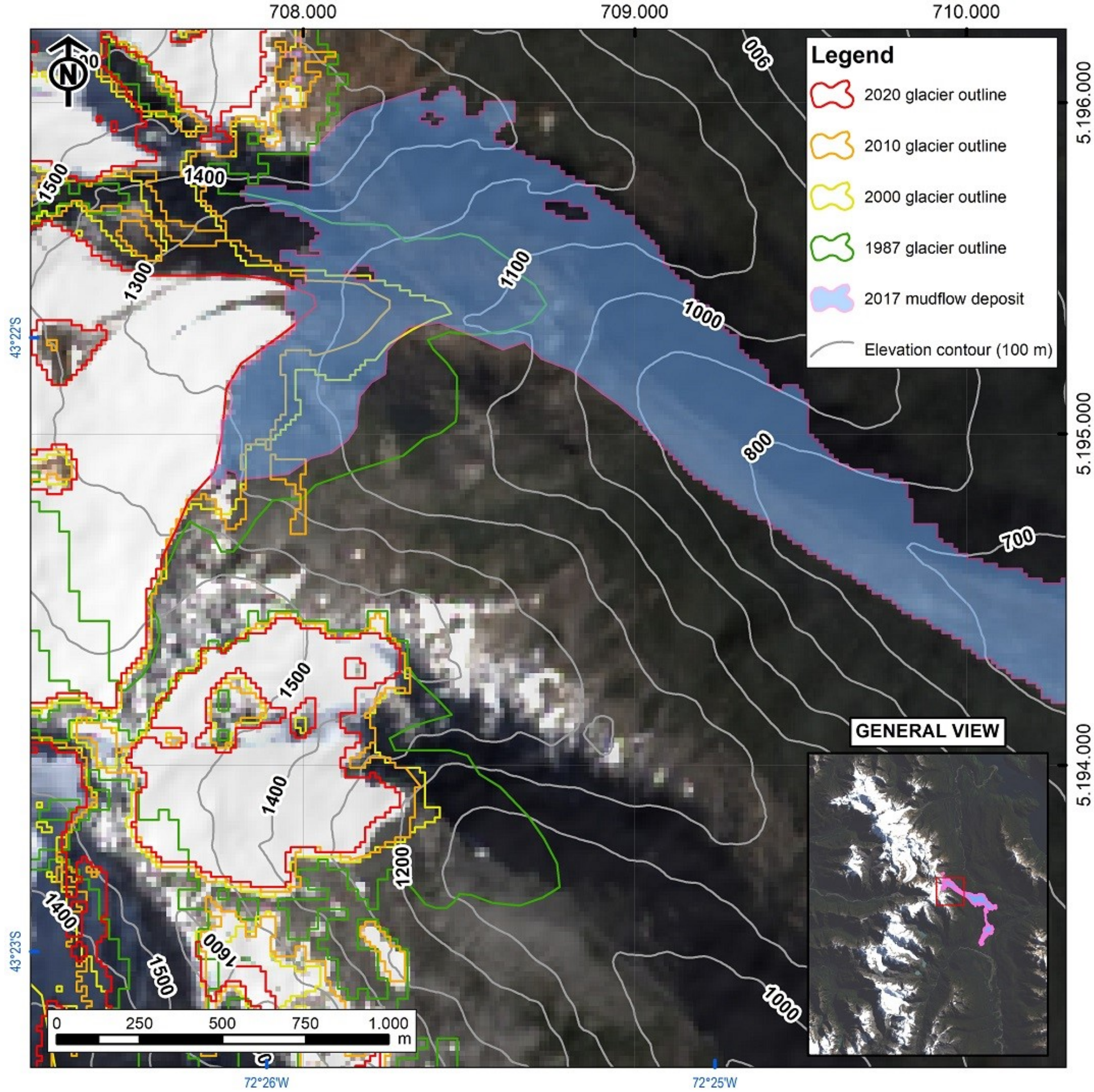

Figure 2: 1987-2020 glacier outlines at Yelcho glacier and source area of the 2017 mudflow

Figures 3 to 9 illustrates the glacier retreat along the Yelcho range through 1987 to 2020.

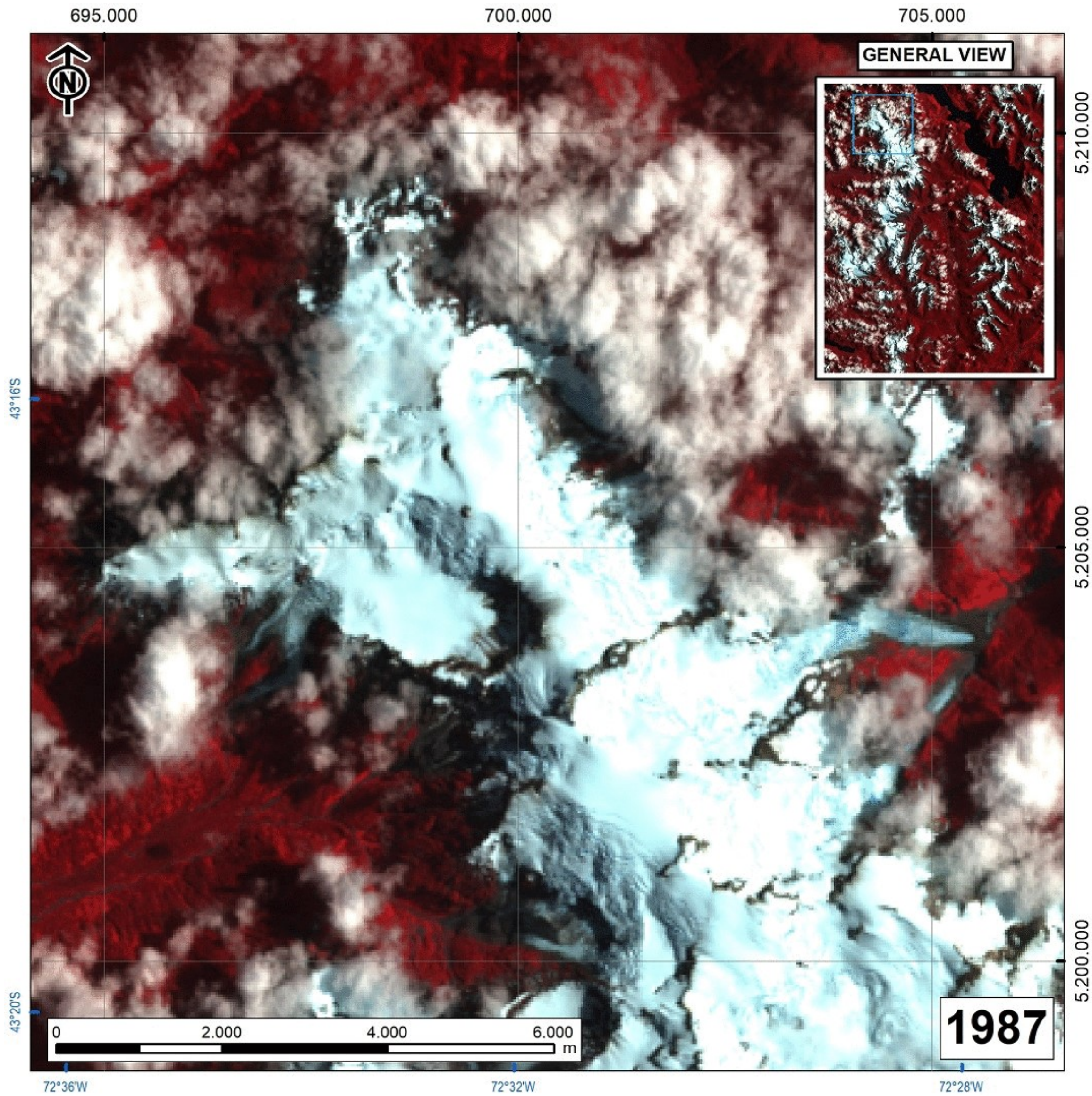

Figure 3: Animation showing the glacier retreat at Yelcho range, northern zone

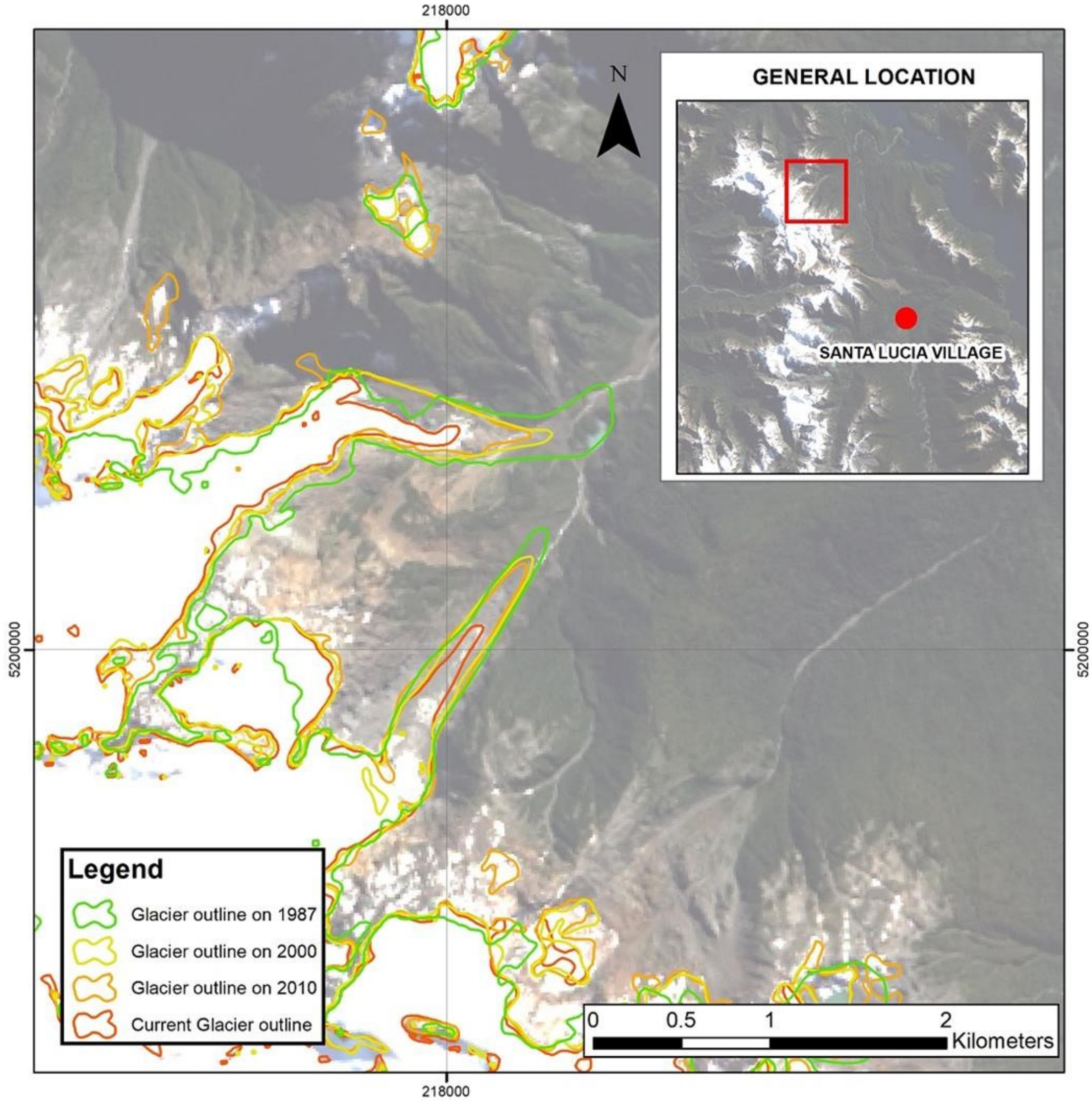

Figure 4: 1987-2020 glacier outlines at Yelcho range, northern portion

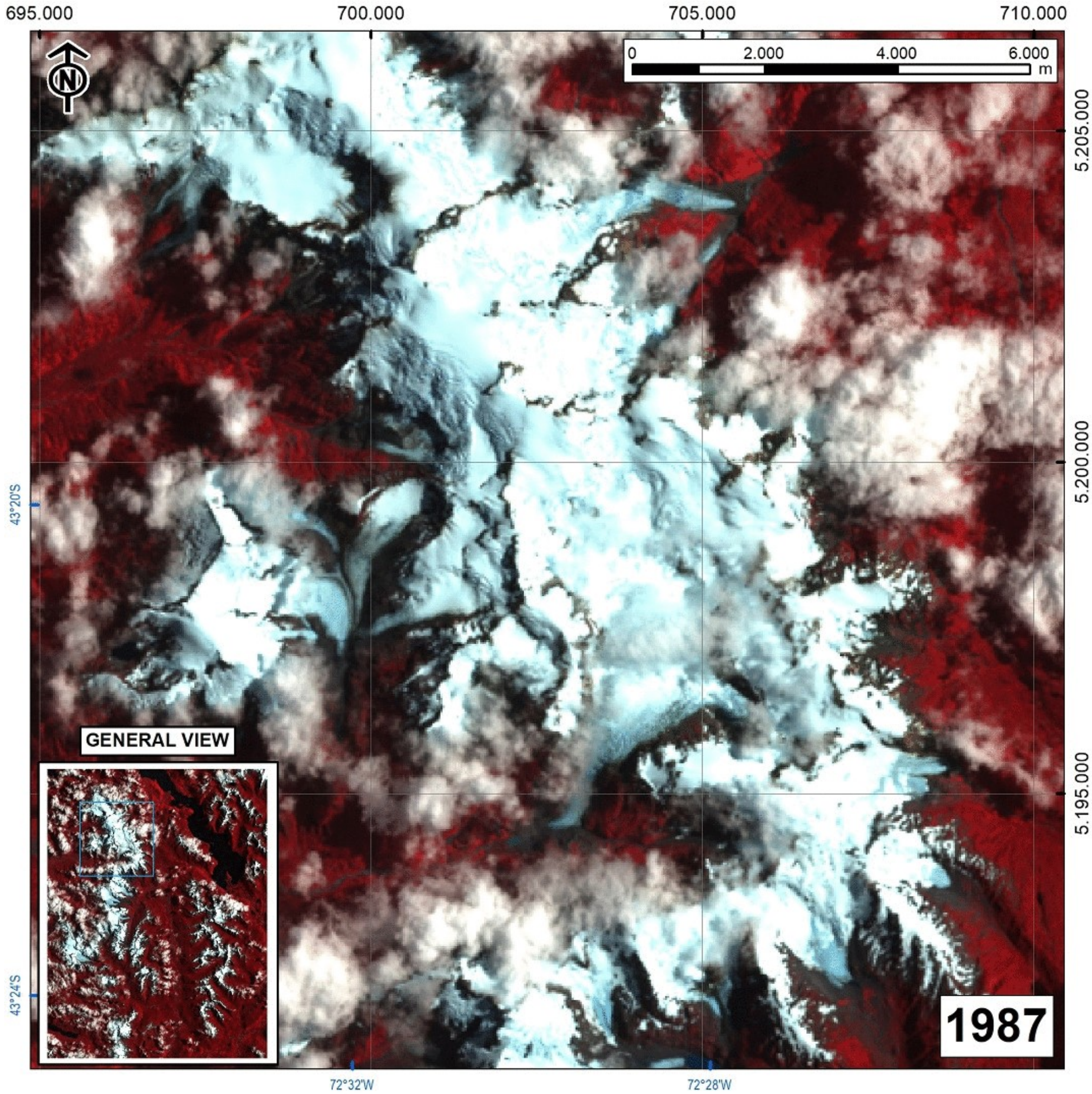

Figure 5: Animation showing the glacier retreat at Yelcho range, central zone

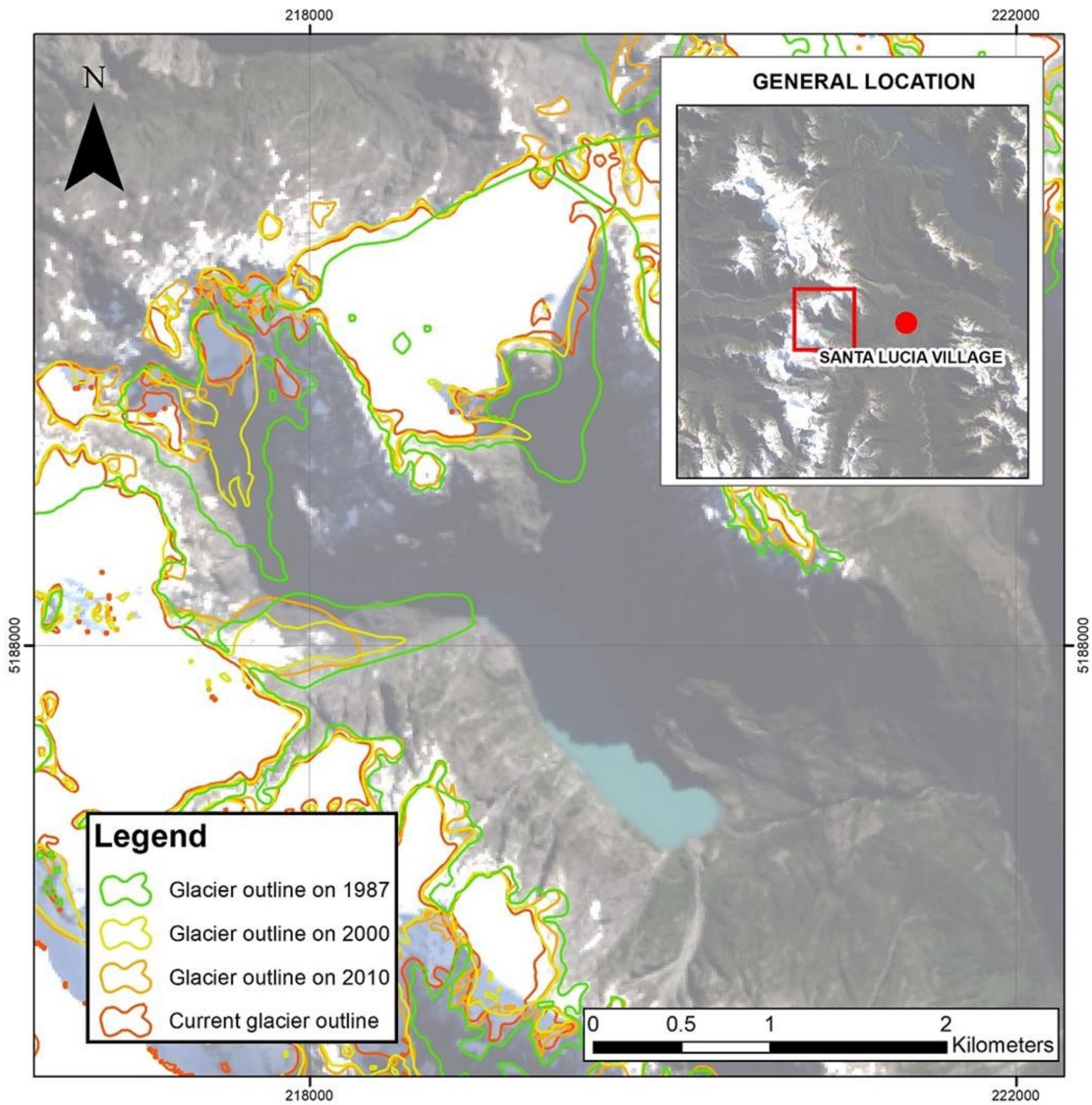

Figure 6: 1987-2020 glacier outlines at Yelcho range, central portion

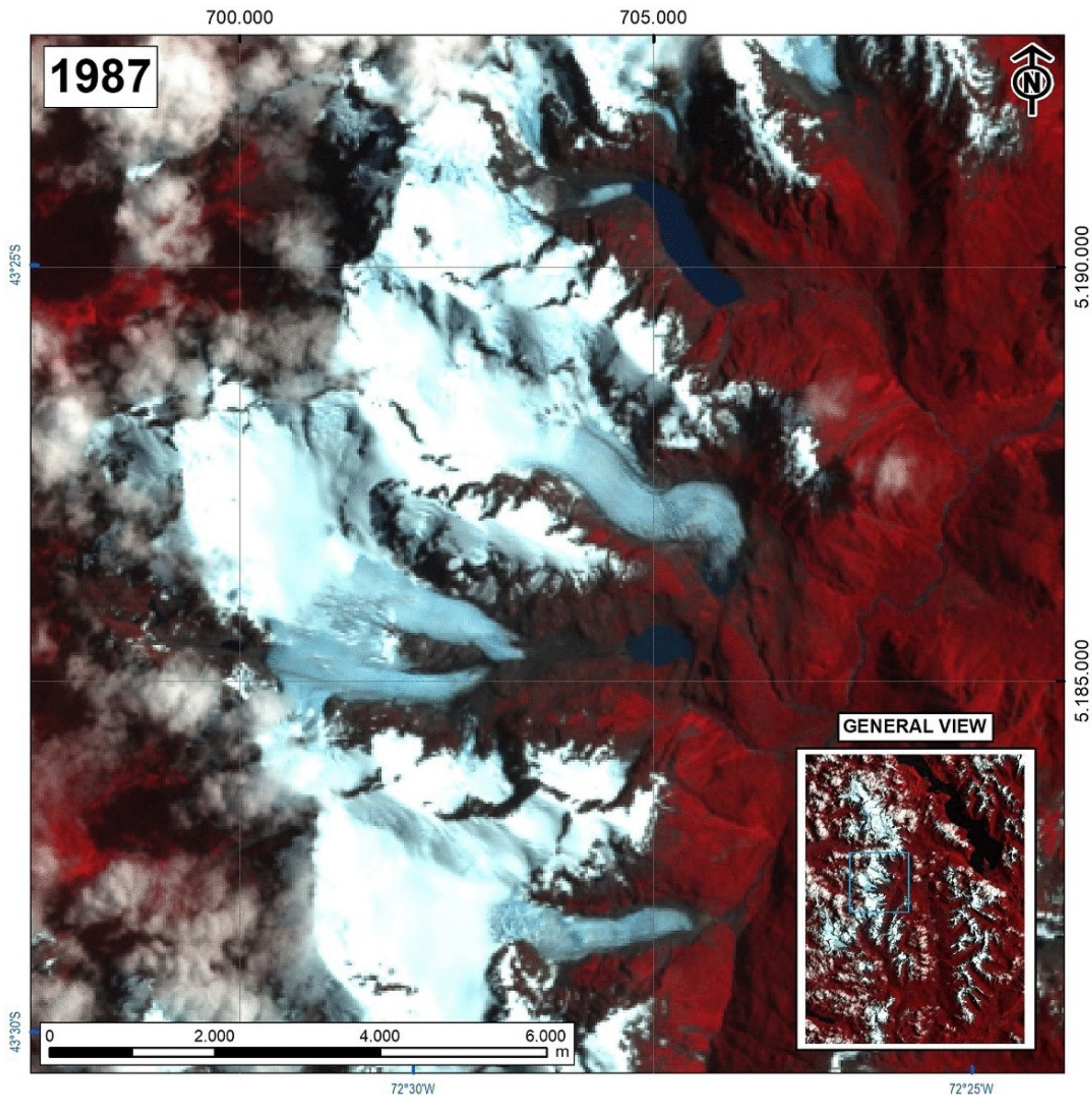

Figure 7: Animation showing the glacier retreat at Yelcho range, southern zone

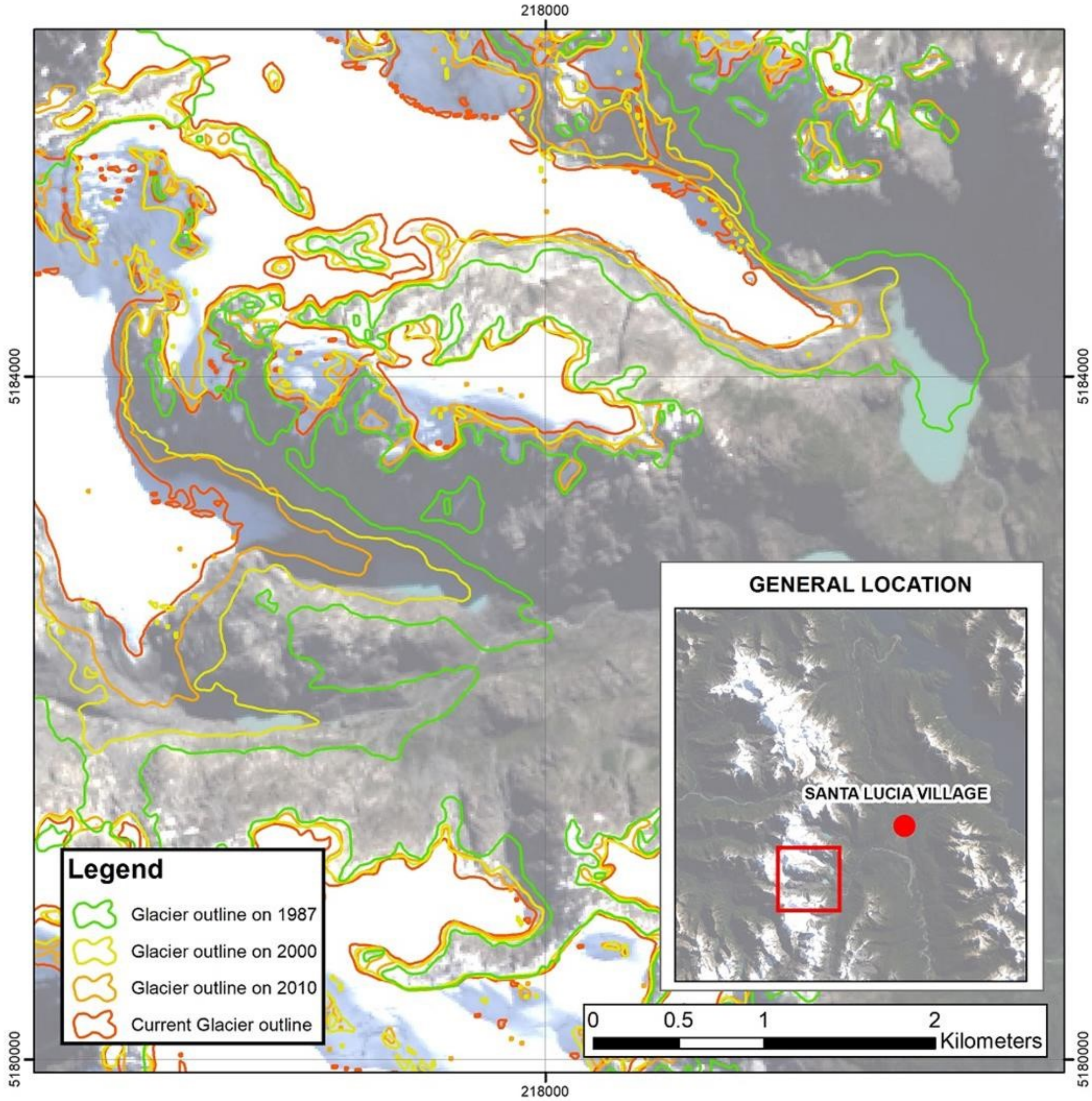

Figure 8: 1987-2020 glacier outlines at Yelcho range, southern portion

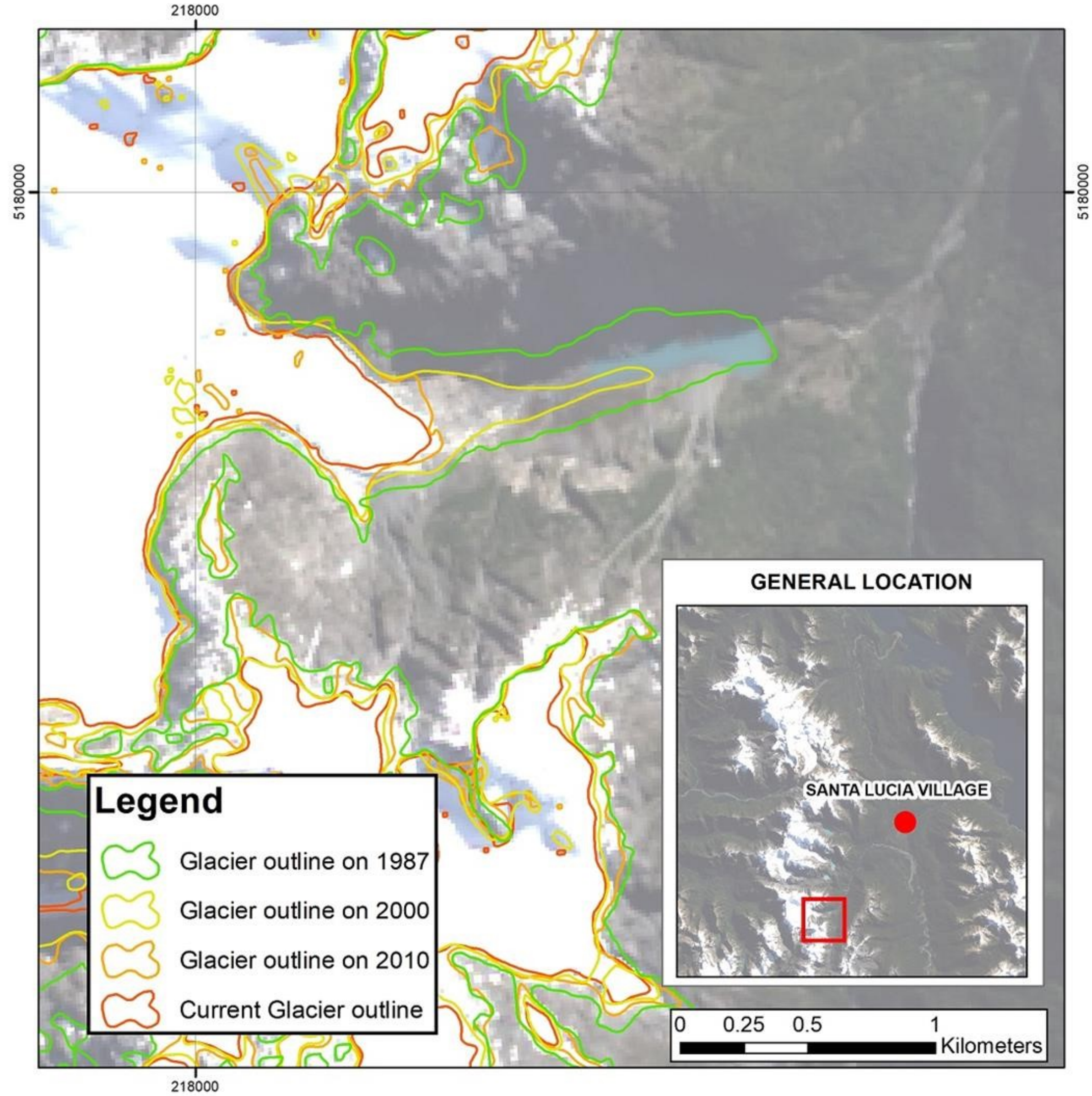

Figure 9: 1987-2020 glacier outlines at Yelcho range, south-southern portion

PROGLACIAL LAKES

Figure 10 resumes the linear retreat of glaciers and the cummulative growth of proglacial lakes shown in Figure 11, whereas Figure 12 illustrates the increased elevation of those glacier through time. Codes refers to the Chilean Public Glacier Inventory (https://dga.mop.gob.cl/estudiospublicaciones/mapoteca/Inventarios /Glaciares_Nacional.zip).

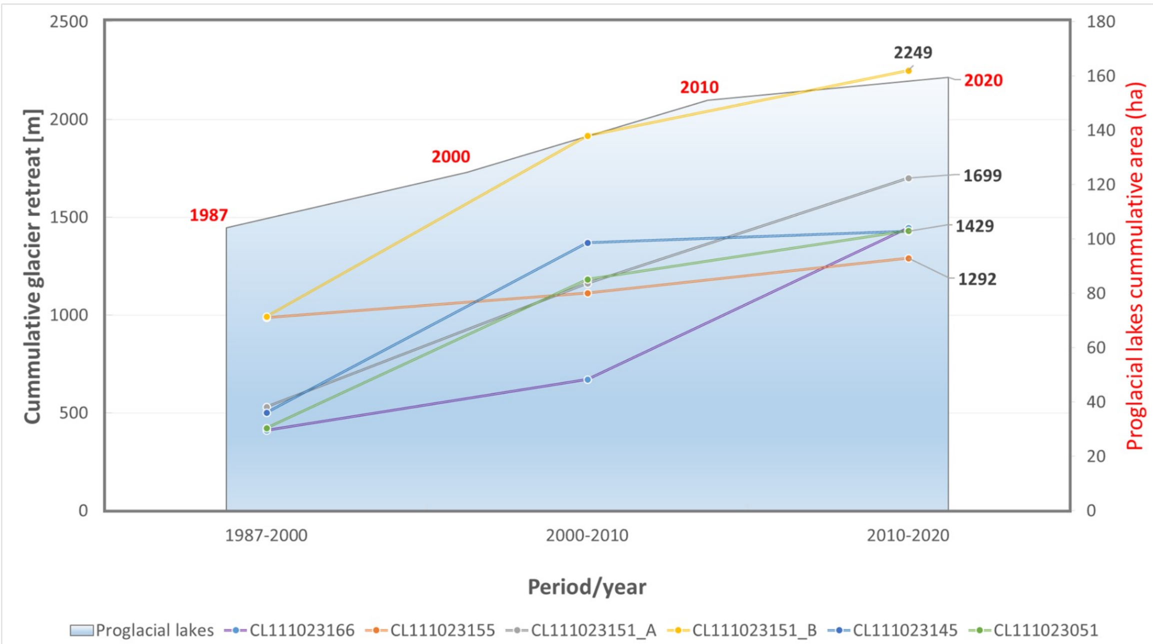

Figure 10: Cummulative glacier retreat and proglacial lake growth

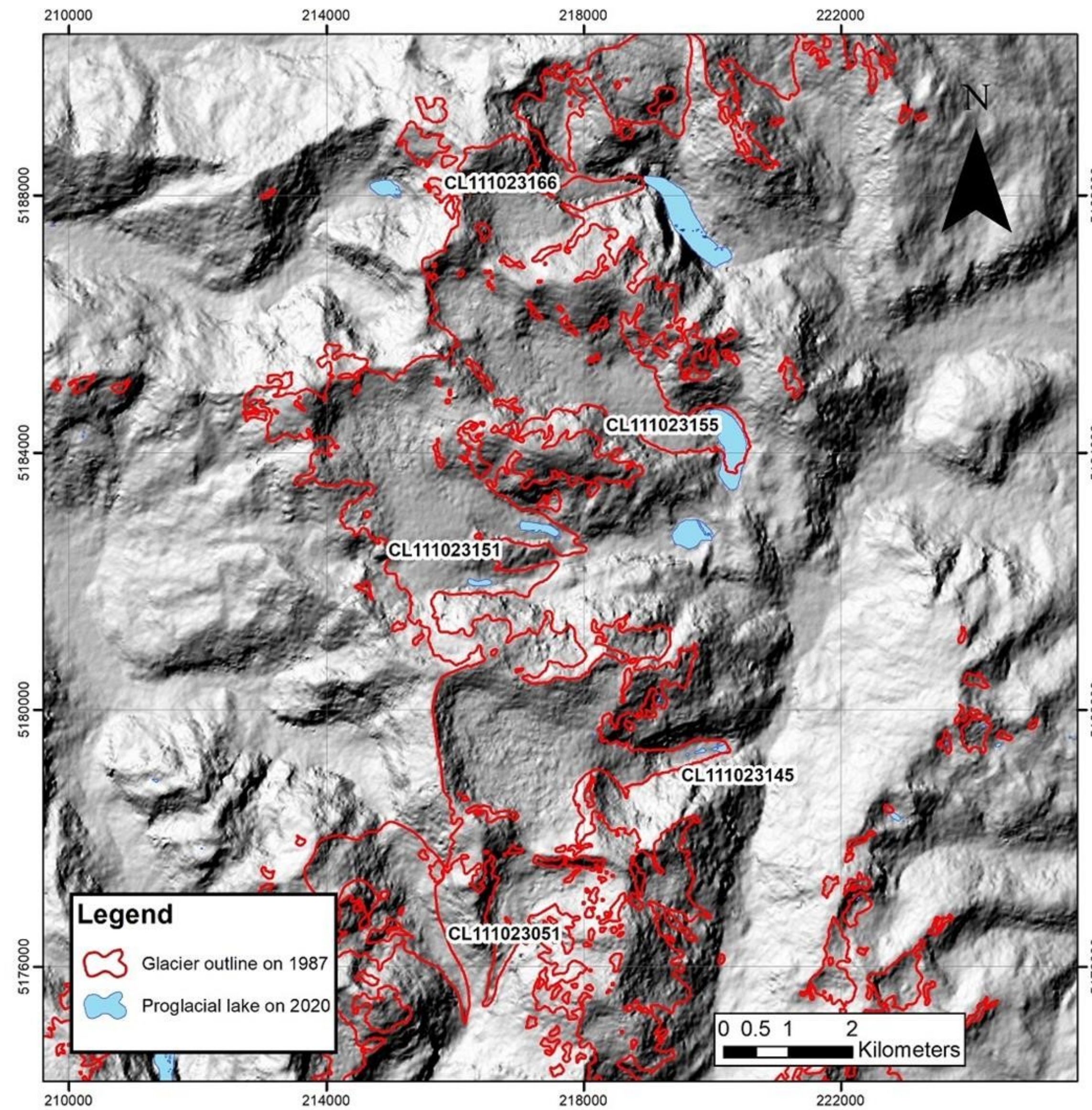

Figure 11: Contrast between proglacial lakes at they current extension and 1987 glacier outlines

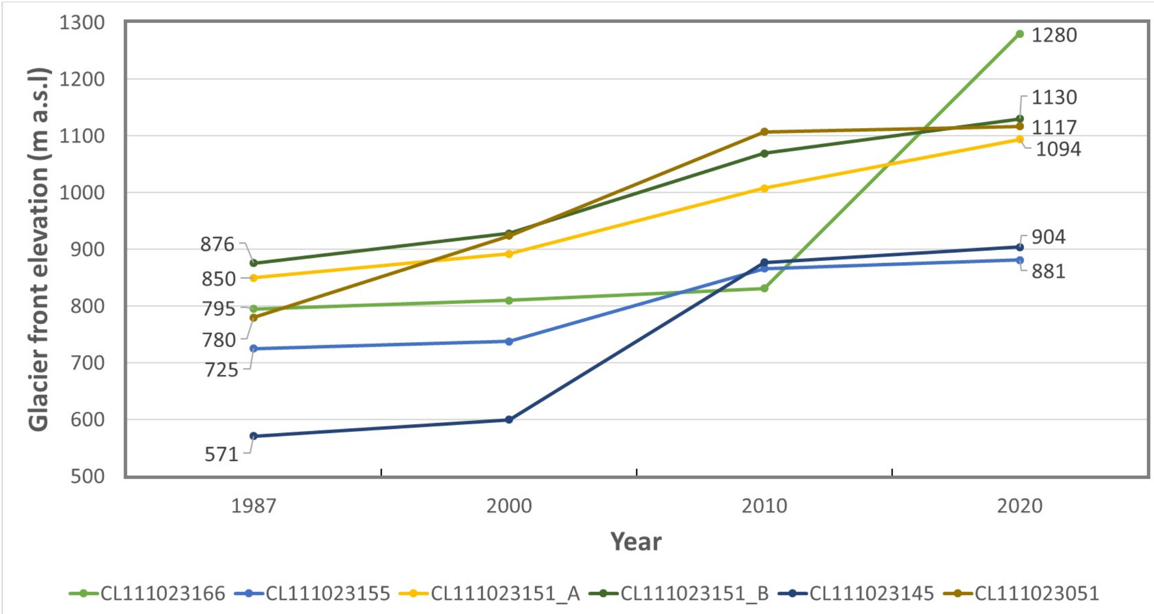

Figure 12: Glacier front position elevation from 1987 to 2020

HAZARD MANAGEMENT

Figure 13 shows the slope distribution of the study area. The majority of the glacier terminus lies just beneath steep slopes, greater than 50°.

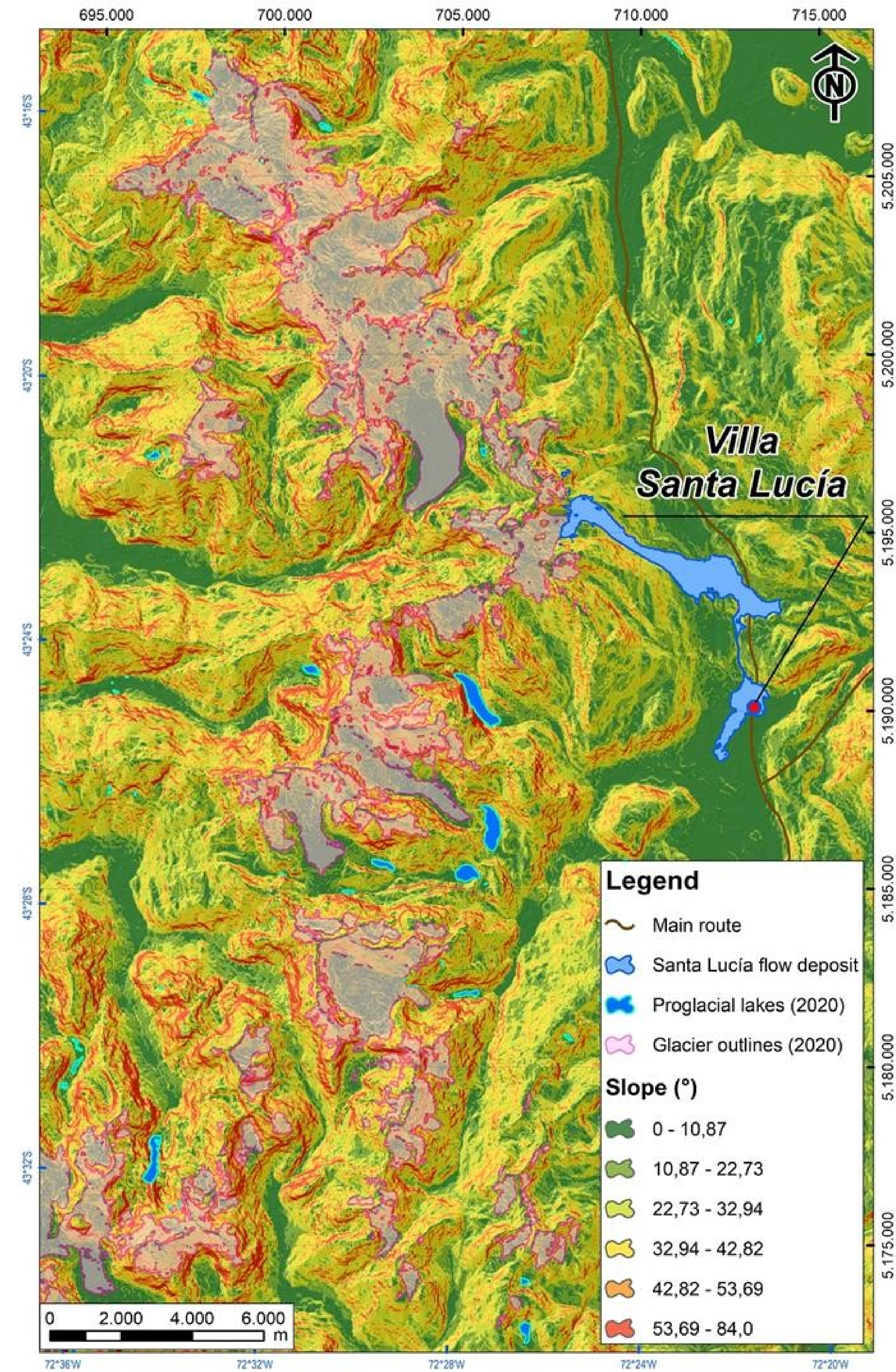

Figure 13: Slope distribution of the Yelcho range and its surroundings

Figure 14 illustrates three mass movements deposits near glaciers. Upper left first reported by Iribarren-Anacona *et al*. (2014).

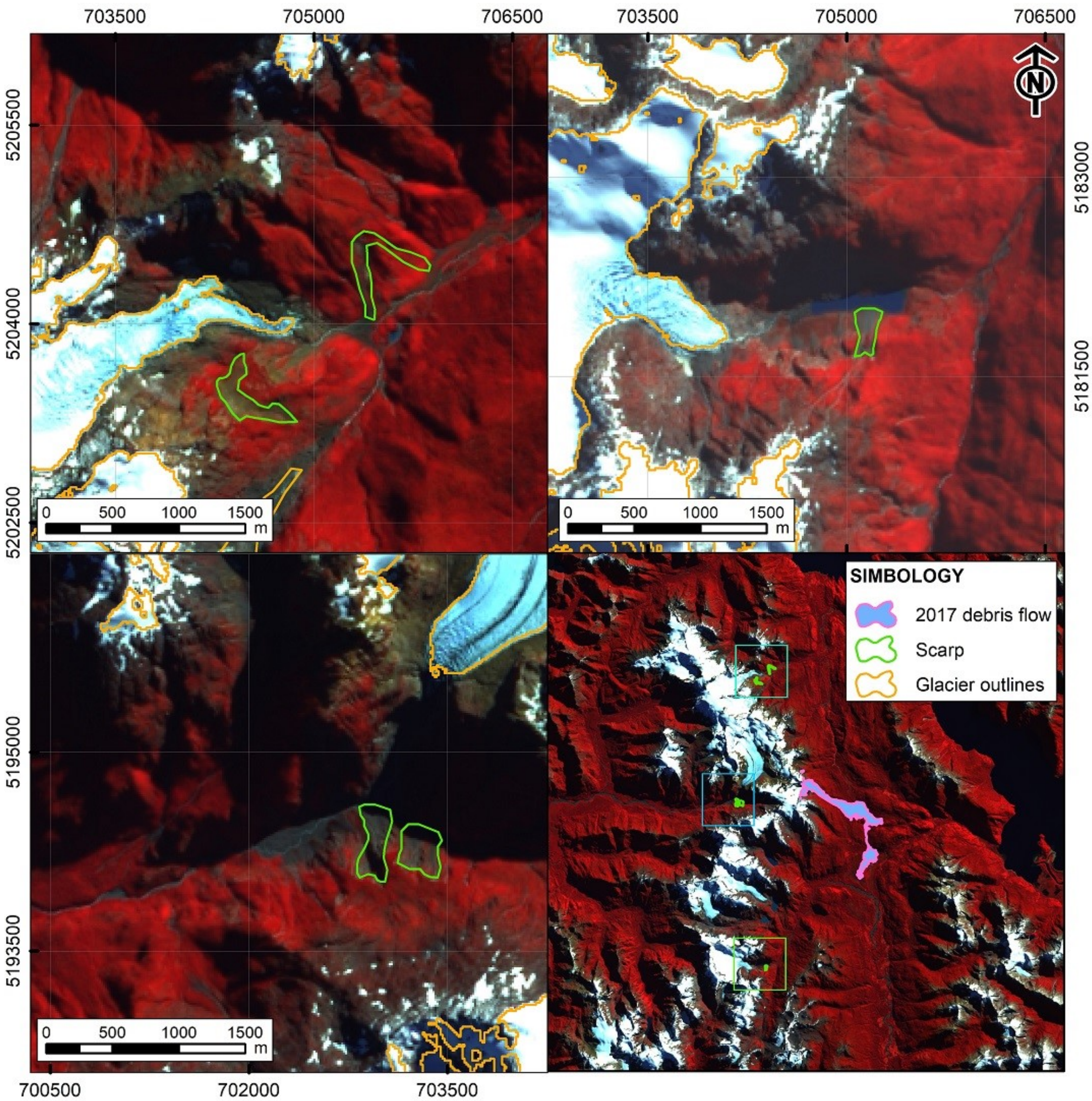

Figure 14: Identified mass movements after glacier retreat

SUMMARY

3D summary (https://skfb.ly/6XsxV)

- A complex mass movement triggered by extreme rainfall involved debris, water and glacial ice killed 22 people at Villa Santa Lucía on 2017

- The region is characterized by steep slopes and ongoing mass movements near the glaciers front

- Yet, little is known regarding the variations of the surrounding glaciers above the Yelcho range

- We estimate glacier retreat rates up to 90 m/year for the last decade

- At least 10 proglacial lakes were formed between 1987 and 2020 due to glacier retreat

- Local communities must have access to this kind of open-access data

- Increasing knowledgement of the region and its dynamics is key for resilience and adaptation

AUTHOR INFORMATION

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Martín Bustamante: Geographer of the Pontifical Catholic University of Chile (PUC). Currently working at Geoestudios Asesores SA (Chile).

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