Cryosphere and related hazards in High Mountain Asia in a changing climate

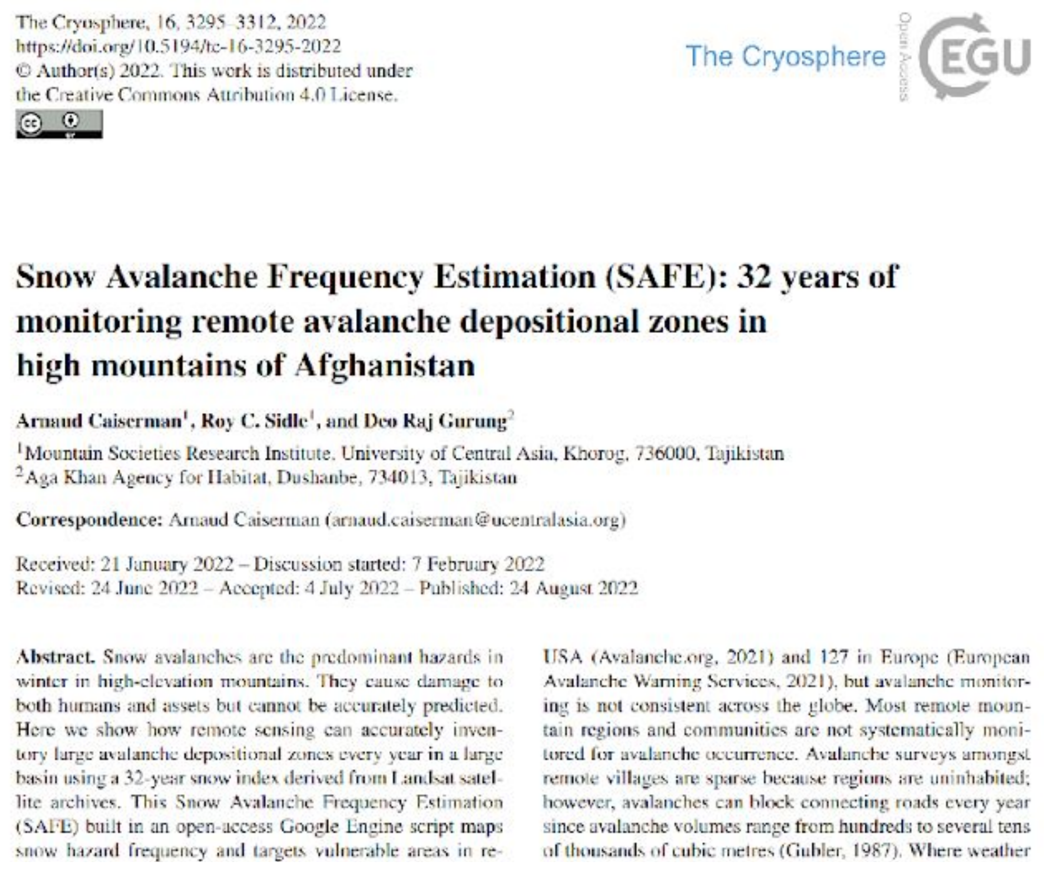
1–4 November 2022 | Almaty, Kazakhstan

Presenter(s): Arnaud Caiserman, Mountain Societies Research Institute – University of Central Asia; arnaud.caiseman@ucentralasia.org

Date: 03/11/2022

Systematic monitoring of snow hazards using Landsat archives: the new approach of Snow Avalanches Frequency Estimation script

The publication of SAFE script


The Cryosphere, 16, 3295–3312, 2022
https://doi.org/10.5194/tc-16-3295-2022
© Author(s) 2022. This work is distributed under
the Creative Commons Attribution 4.0 License.

The Cryosphere

Snow Avalanche Frequency Estimation (SAFE): 32 years of monitoring remote avalanche depositional zones in high mountains of Afghanistan

Arnaud Caiserman[1], Roy C. Sidle[1], and Deo Raj Gurung[2]

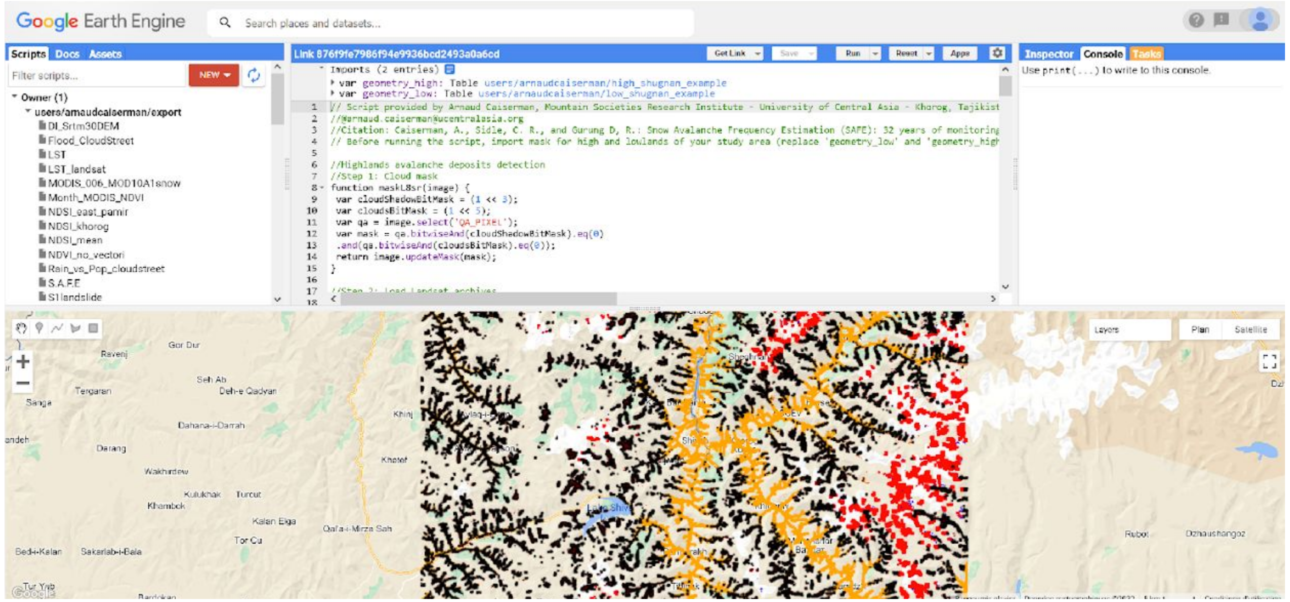
[1]Mountain Societies Research Institute, University of Central Asia, Khorog, 736000, Tajikistan
[2]Aga Khan Agency for Habitat, Dushanbe, 734013, Tajikistan

Correspondence: Arnaud Caiserman (arnaud.caiserman@ucentralasia.org)

Received: 21 January 2022 – Discussion started: 7 February 2022
Revised: 24 June 2022 – Accepted: 4 July 2022 – Published: 24 August 2022

Abstract. Snow avalanches are the predominant hazards in winter in high-elevation mountains. They cause damage to both humans and assets but cannot be accurately predicted. Here we show how remote sensing can accurately inventory large avalanche depositional zones every year in a large basin using a 32-year snow index derived from Landsat satellite archives. This Snow Avalanche Frequency Estimation (SAFE) built in an open-access Google Engine script maps snow hazard frequency and targets vulnerable areas in re-

USA (Avalanche.org, 2021) and 127 in Europe (European Avalanche Warning Services, 2021), but avalanche monitoring is not consistent across the globe. Most remote mountain regions and communities are not systematically monitored for avalanche occurrence. Avalanche surveys amongst remote villages are sparse because regions are uninhabited; however, avalanches can block connecting roads every year since avalanche volumes range from hundreds to several tens of thousands of cubic metres (Gubler, 1987). Where weather



An open access script (java) available on Google Engine platform, using Google super computers

Required: minimum of 8 Gb RAM; a descent internet connection

The concept of SAFE

The snow avalanches deposits are still detectable in the riparian areas, late winter (clear sky conditions for images)

What it does: annual mapping of deposits at the end of the season

Key parameters: time (later winter) and spatial mask (riparian zones)

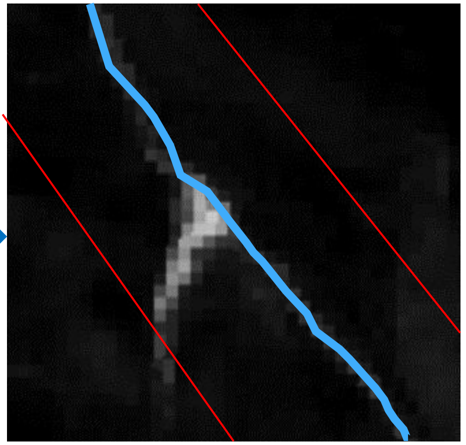
What data: Landsat archives (4,5,7,8 and 9), SRTM30 and MODIS monthly snow coverage

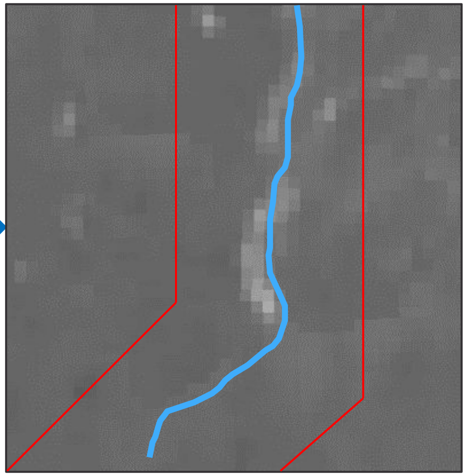
What index? NDSI (transferable for Landsat)

Output (a): 33 years **frequency map** of avalanches

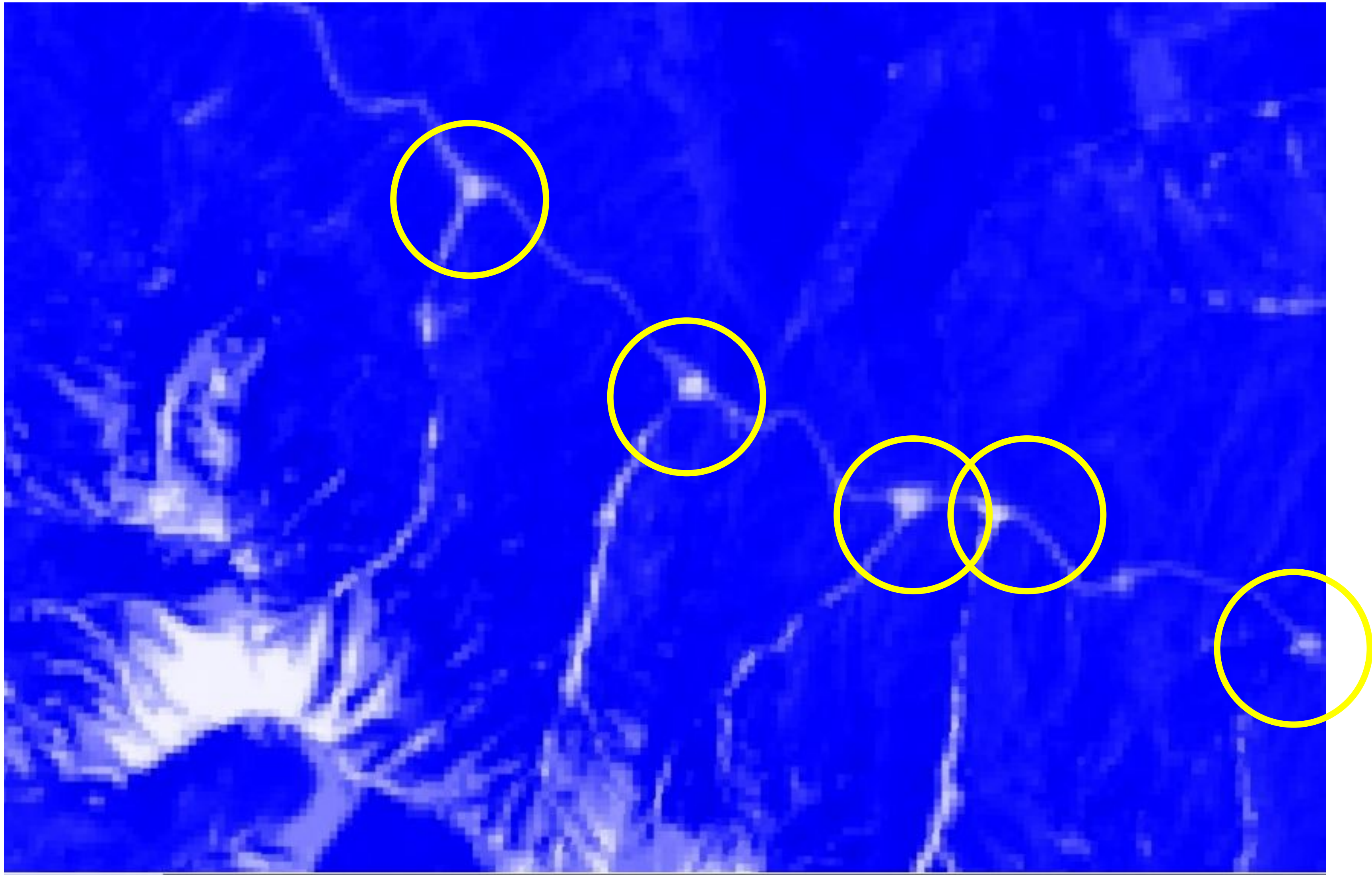
Output (b): the **list of the most vulnerable** villages, roads and powerlines

Output (c): the **trend** of avalanches number and surface area

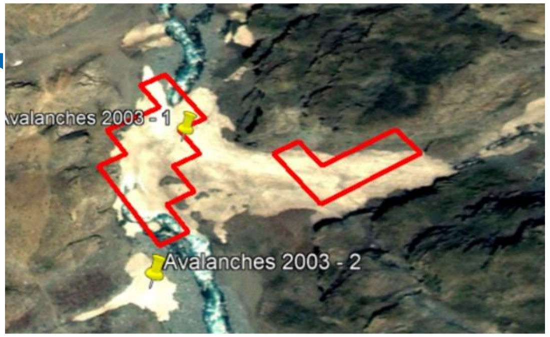




The concept of SAFE



Validation of SAFE



Comparison with Google Earth

Probability of Detection: 0.77

Positive Predictive Values: 0.96

Reference	Accuracy (%)	Dataset
Malnes et al., 2015	53	S1
Vickers et al., 2016	60	S1
Leinss et al., 2020	70	S1 and TerraSAR-X
Karas et al., 2021	70	S1
Hafner et al., 2021	74	SPOT
Eckerstorfer et al., 2017	75	S1
Yang et al., 2020	75	S1
Martinez-Vazquez	76	GB-SAR LISA
SAFE	**77***	**Landsat**
Tompkin and Leinss, 2021	81*	S1
Yarivan et al., 2020	90	Google Earth imagery
Singh et al., 2019	93*	L8
Bühler et al., 2018	95	DTM

SAFE and other avalanches remote sensing method accuracy (* POD)

Validation of SAFE

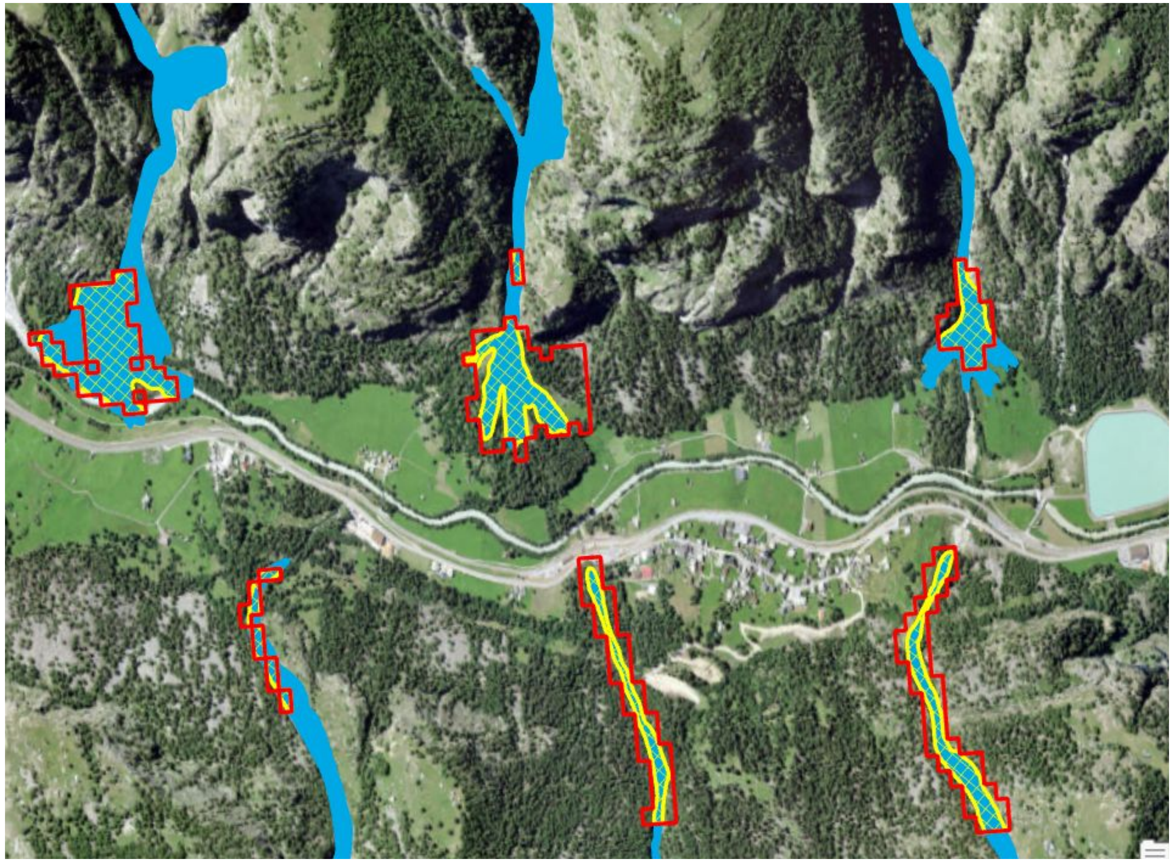
Comparison of SAFE automatically extracted deposits using Landsat with manually digitized avalanches using high resolution images (SPOT-6)

Overlap of the two datasets: **62%** of common surface

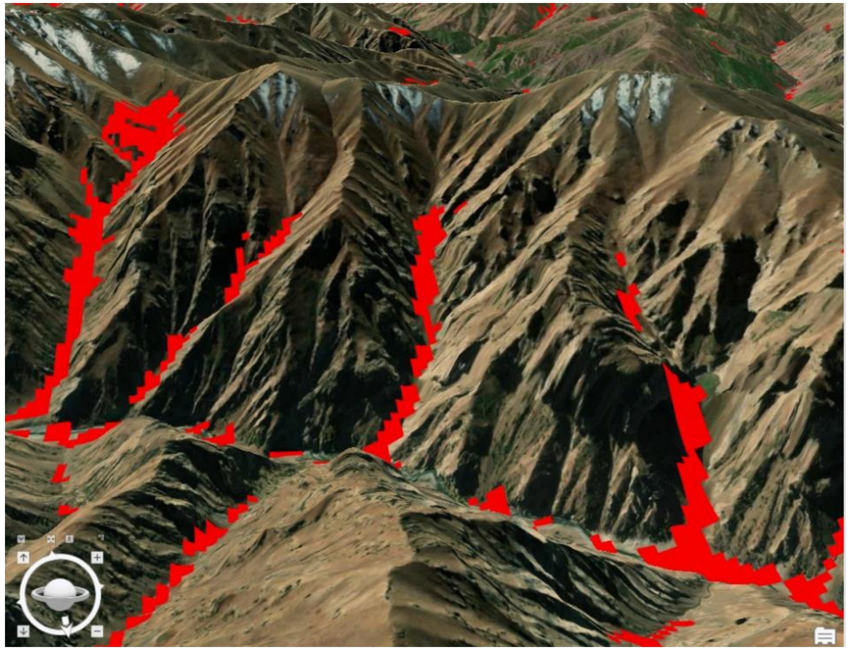
SAFE is **time saving** and **accurate** enough to extract the deposits

SAFE can be automatically run over large areas. For example in Afghanistan:

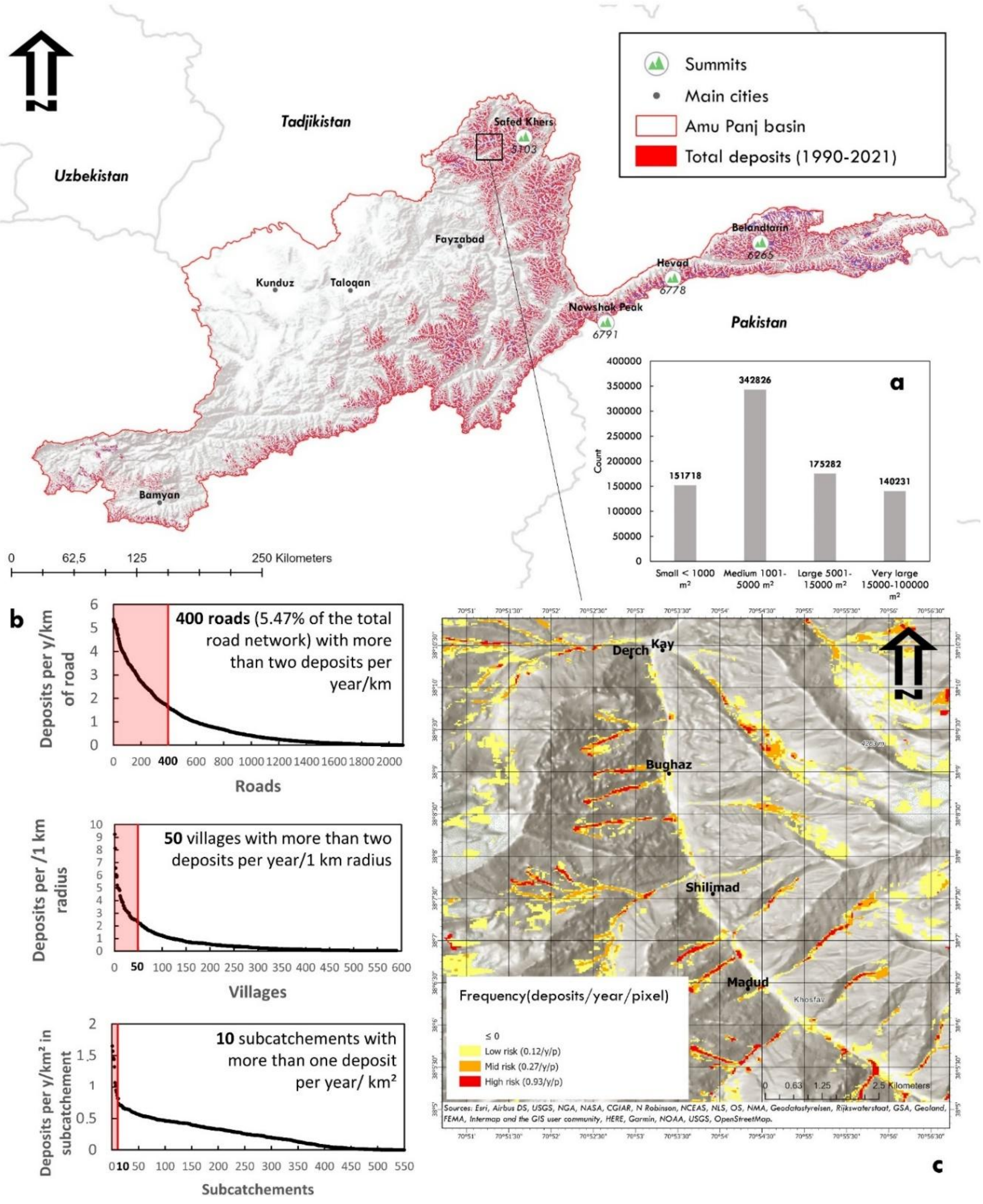
- **30,000** km^2,
- **32** years of deposits,
- **12** hours for all years with a **2.2** Gb/s connection



An illustration



3-Dimension view of the 32 years avalanche depositional zones maps in Khinj village in Afghanistan (*ArcGisPro*)



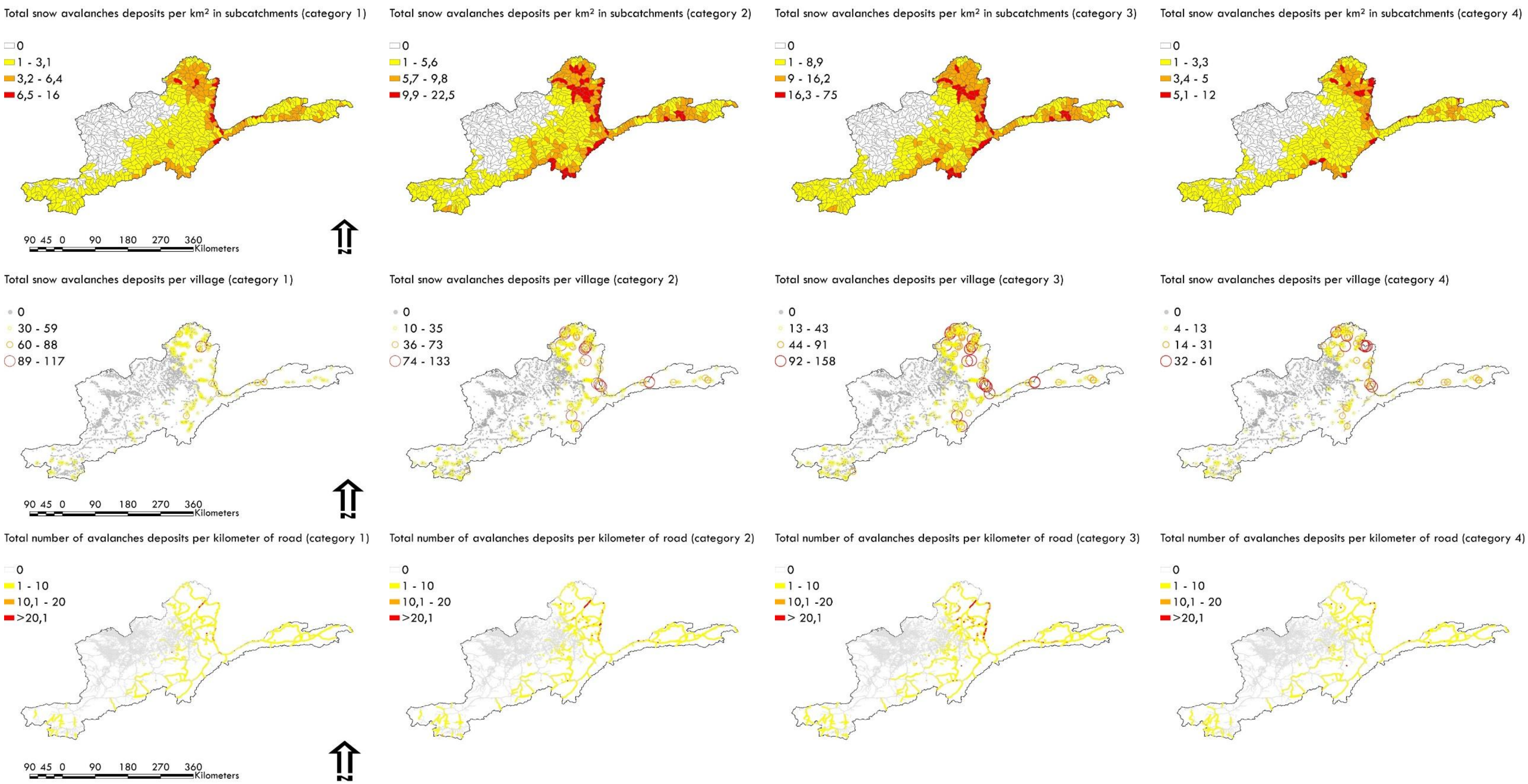
Yearly inventory map of snow avalanche depositional zones in the Amu Panj basin: 1990-2021:
a, Surface area classification;
b, Avalanche depositional zone frequency per number of roads, villages, and subcatchments in the basin;
c, An example map of avalanche frequency

Vulnerabilities and priorities

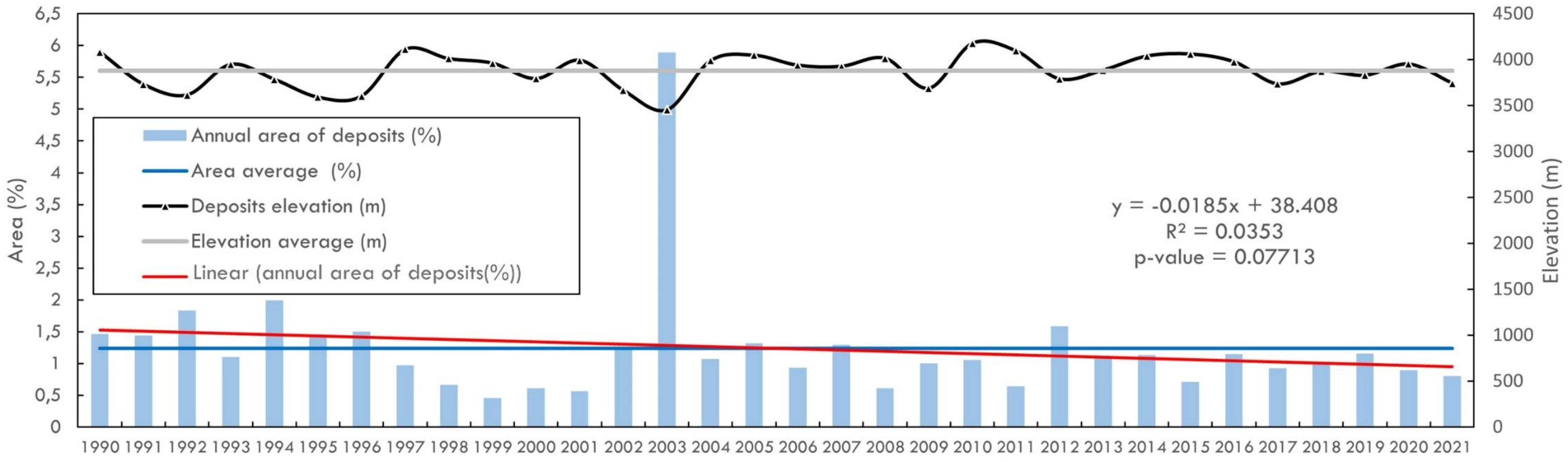
Subcatchments

Villages

Roads

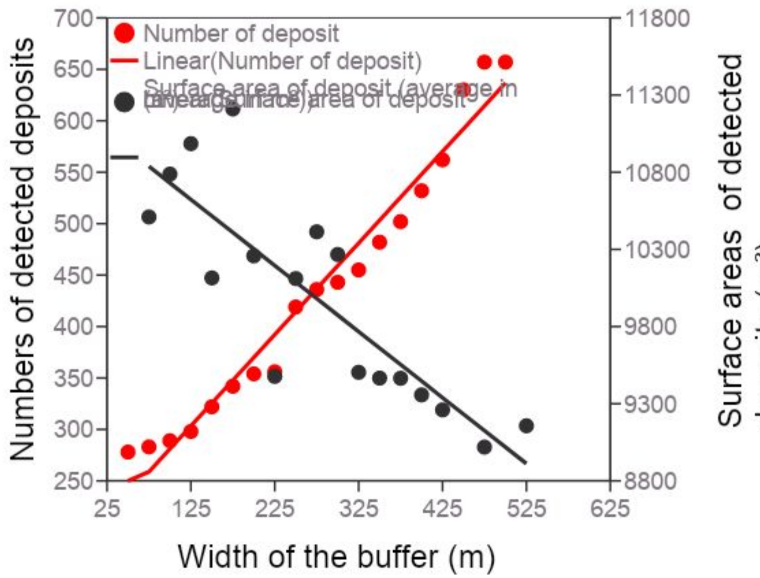


Evolution of avalanches: no significant trends

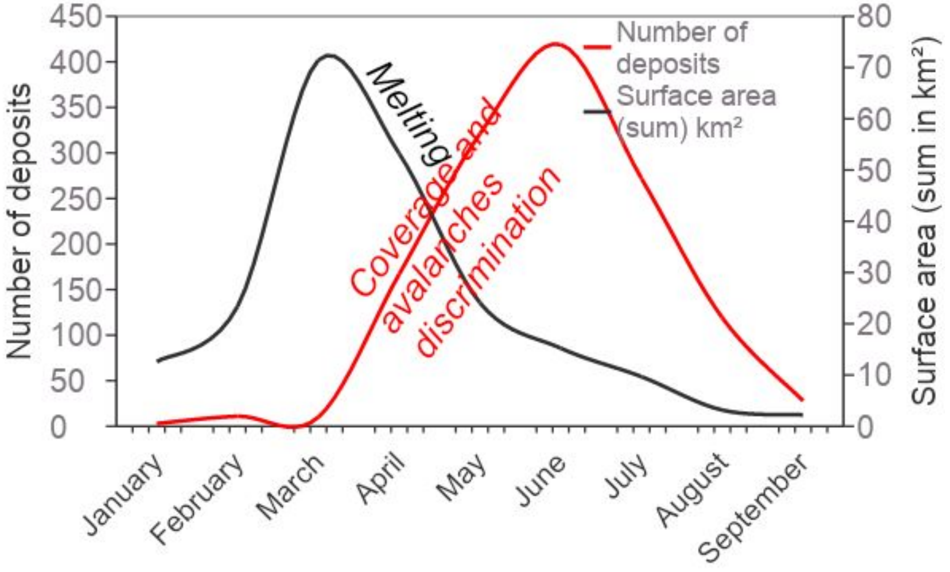


Snow depositional zone area and elevation trends since 1990 in the Amu Panj basin. Elevation was calculated within each polygon of avalanche deposits using SRTM-30 Digital Elevation Model. Mann-Kendall p-value 0.05 test was conducted avalanche to assess the significance of the trend.

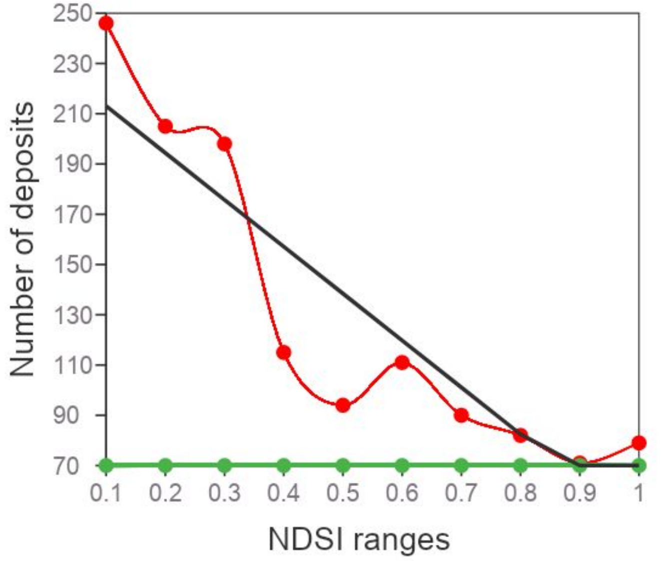
A word for the users of SAFE



Spatial Mask



Temporal Mask



NDSI

Our recommendations:

- **200** m buffer
- **0.31 to 1** NDSI threshold
- Late **April** to Late **June**

Concluding word

SAFE is a universal script, duplicable anywhere where avalanches are predominant

SAFE was validated and showed good performances

The script is open-access and does not require significant computer skills

A support for decision makers, especially on road and other infrastructures planning

SAFE also looks at remote areas, where few if not no knowledge is available on avalanches

Regional and international scales

MSRI current work on SAFE:

Two projects in Tajikistan (WFP and WB), trainings and script improvement

Thank you

Caiserman, A., 2022. Snow Avalanche Frequency Estimation (SAFE), Zenodo Repository, URL: https://zenodo.org/record/6973757#.Y1aMluTP13h

Nature Research Highlight, 2022. Avalanches in remote peaks are revealed with old satellites' aid. Nature 609, 224–224. https://doi.org/10.1038/d41586-022-02772-y

https://jobs.chronicle.com/job/37350300/**director**-mountain-societies-research-institute-graduate-school-of-development

https://www.timeshighereducation.com/unijobs/listing/315050/**research-fellow**-mountain-societies-research-institute-msri-/

unesco

Aga Khan Agency for Habitat

ICIMOD

CARGC

GLOFCA

ADAPTATION FUND