Statistically-based modelling of rock glacier activity

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1 INTRODUCTION AND AIM

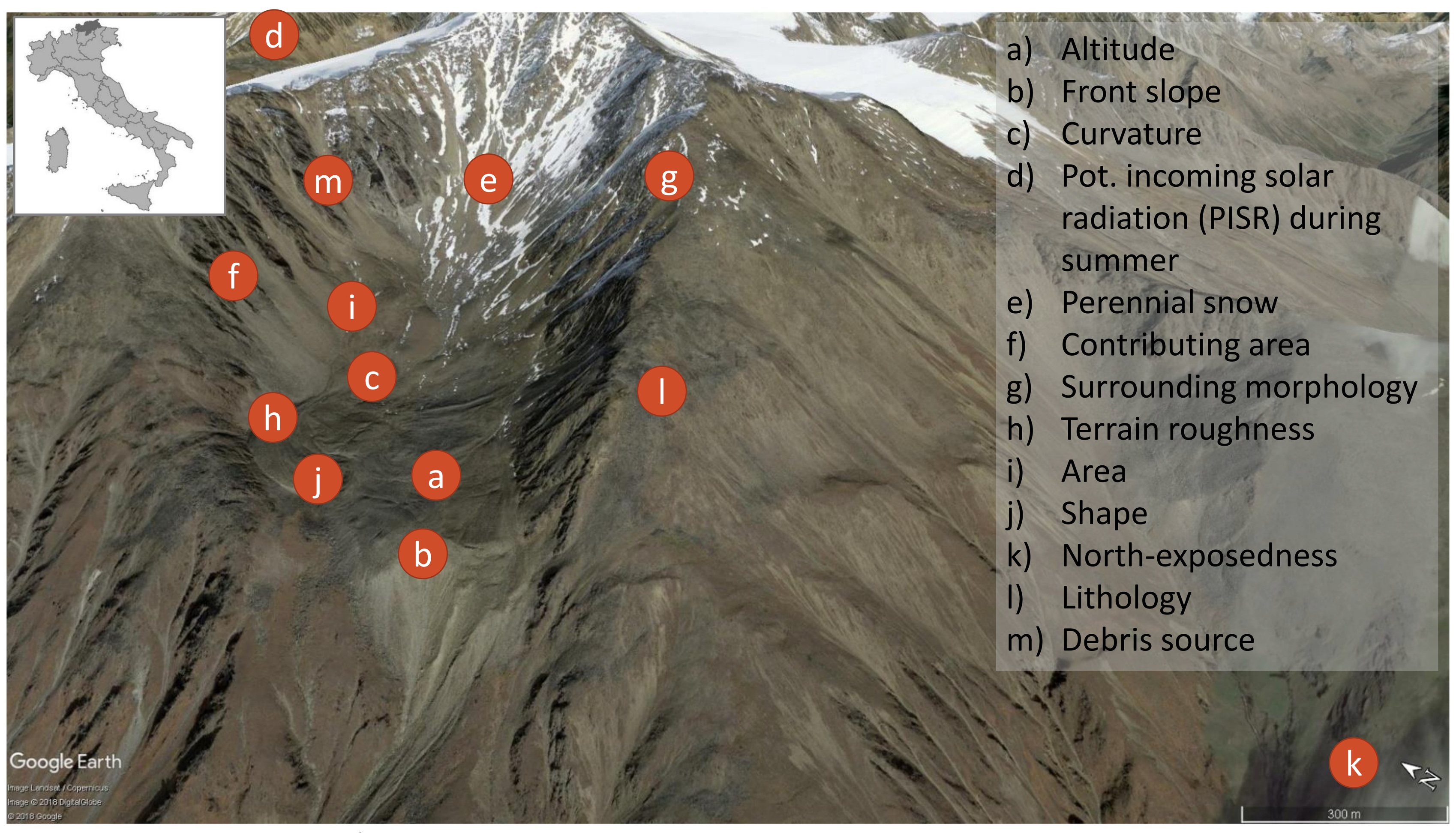


Fig. 1: Similaungrube rock glacier, Schnalstal/Val Senales, Italy

The activity status of rock glaciers is an important information when assessing different aspects of periglacial environments such as potential hazards or the supply of fresh water. Various features of rock glaciers and their surrounding environment may be suitable predictors to describe their activity status (see Fig.1).

In the present work, the activity status of rock glaciers (intact/relict) was analyzed statistically (e.g. univariate statistics, multiple variable regression) at regional scale in order to explore associated environmental controls. The study was conducted for the Autonomous Province of South Tyrol (Italy).

2 MATERIALS AND METHODS

The rock glacier inventory of South Tyrol as well as the DEM were the main data source for this study. The inventory contains 1779 mapped rock glaciers (240 active, 59 inactive, 1245 relict and 235 rock glaciers whose activity was not identified). Explanatory variables were assigned to sample points that also represent the activity status of the respective rock glaciers (Tab. 1, Fig. 2). The distribution of numerical values was elaborated by means of (conditional) frequency plots. Single-predictor logistic regression models allowed to investigate the individual discriminatory power of predictors on the basis of the area under the ROC curve (AUROC). Finally, two multiple variable logistic regression models were applied: (i) **data-driven** (lowest AIC) and (ii) **heuristic-based**. Both models were then used to "predict" the activity status of the yet unclassified rock glaciers of the inventory.

Type	Group	Variable	Levels/ Unit	Tool	Source	Reference
Response		Activity	Intact/ relict		RG inventory	Bollmann et al. (2012)
Predictors	Rock glacier morphology	Front slope	[°]	SAGA GIS/R	DEM 2.5m	Barsch (1996)
		Body curvature	[-]	SAGA GIS/R	DEM 2.5m	Buchli et al. (2018)
		Surface roughness	[-]	SAGA GIS	DEM 2.5m	Barsch (1996)
	Terrain characteristics	Contributing area	[m]	SAGA GIS	DEM 2.5m	Brenning & Trombotto (2008)
		Geomorph. prot. index	[-]	SAGA GIS	DEM 2.5m	Yokoyama et al. (2002)
		Altitude	[m a.s.l.]	-	DEM 2.5m	Haeberli (1990)
		North-exp.	[-]	SAGA GIS, cos(aspect)	DEM 2.5m	Brenning & Trombotto (2008)
	Environment	PISR summer	[kW/m²]	SAGA GIS	DEM 2.5m	Haeberli (1990)
		Distance to perennial snow	[m]	ESRI ArcGIS	Zischg et al. (2012)	Humlum et al. (2007)
	Material	Debris type	Talus/Till		RG inventory	Stötter et al. (2012)
		Major geological zone	Pennic, Südalpin, Ostalpin		GeoBrowser South Tyrol	Matsuoka and Ikeda (2001)
	Geometry	Area	[m²]		RG inventory	Brenning & Trombotto (2008)
		Shape	lobate/ Tongue		RG inventory	Barsch (1996)

Tab. 1: Predictor and response variables

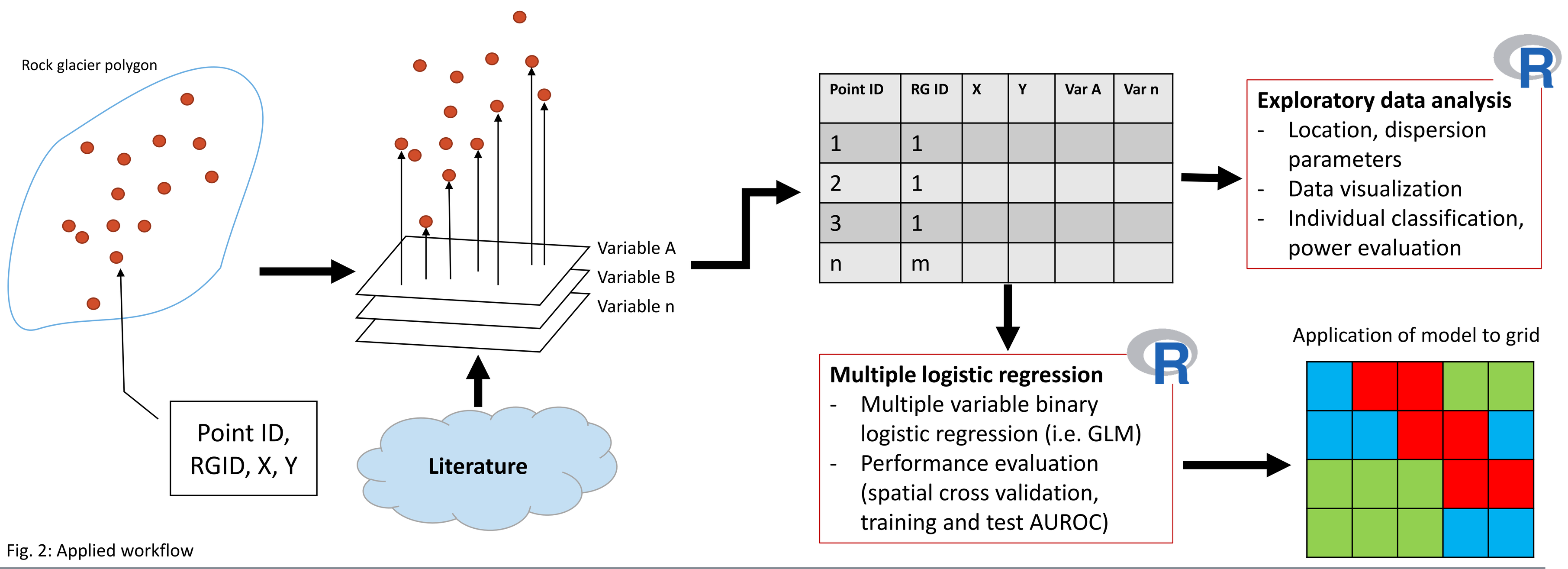
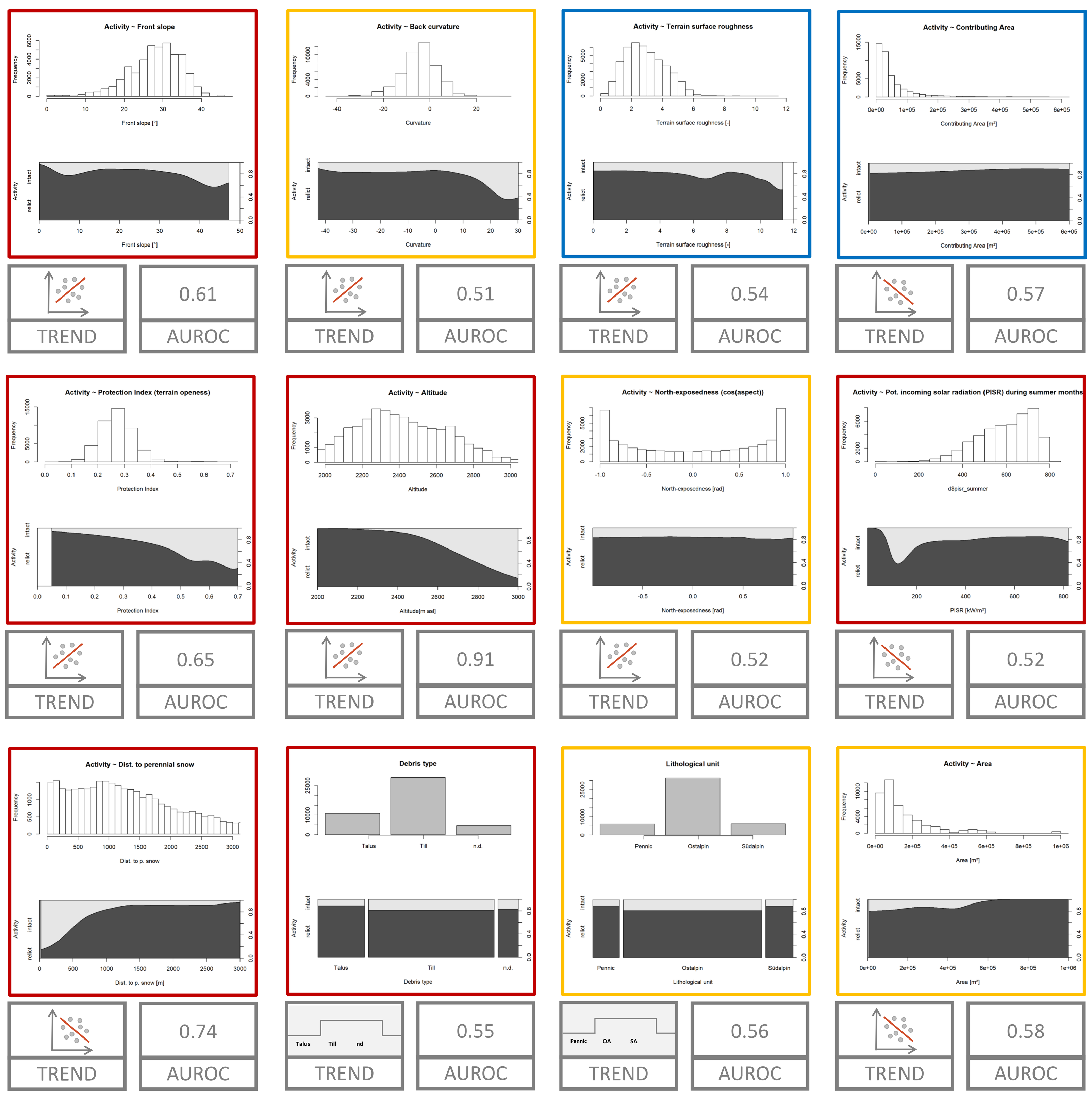
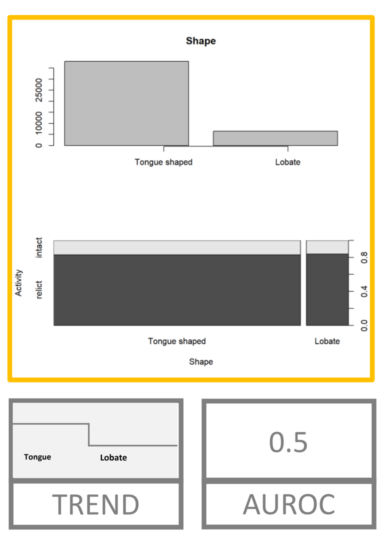


Fig. 2: Applied workflow

3 RESULTS

Fig. 3: Univariate statistical results: (Conditional) distribution, trend and individual discriminatory power (i.e. AUROC). Color coding: Predictors used for the data-driven, heuristic-based, both models





Individual discriminatory power: Altitude and distance to perennial snow fields show the highest performance scores (i.e. AUROCs). Also the front slope and the protection index achieve an acceptable classification power.

Multiple variable activity status model: Spatial model predictions are shown in Fig. 4 (i.e. color of rock glacier polygons). Both variable selection procedures performed similarly in terms of predictive performance, although the data-driven model tends to characterize a higher portion of rock glaciers as ice-free.

4 CONCLUSION

The presented workflow allowed to account for both, existing literature information (e.g. front slope, perennial snow) and terrain data to explore and predict the activity status of rock glaciers. Hereby, open source software products such as R or SAGA GIS were valuable tools.

The exploratory data analysis indicated that besides altitude, the distance to perennial snow patches, the angle of the front slope and the terrain openness are suitable predictor variables. Both multiple variable models performed similarly well to predict the status of an rock glacier on the basis of model independent observations (i.e. AUROC of ~ 0.95). The model classified most of the not yet classified rock glaciers as intact. The application of non-linear classifiers (e.g. GAM) or mixed-effects models are considered as further methodological improvements while also further predictors (e.g. NDVI) will be applied.

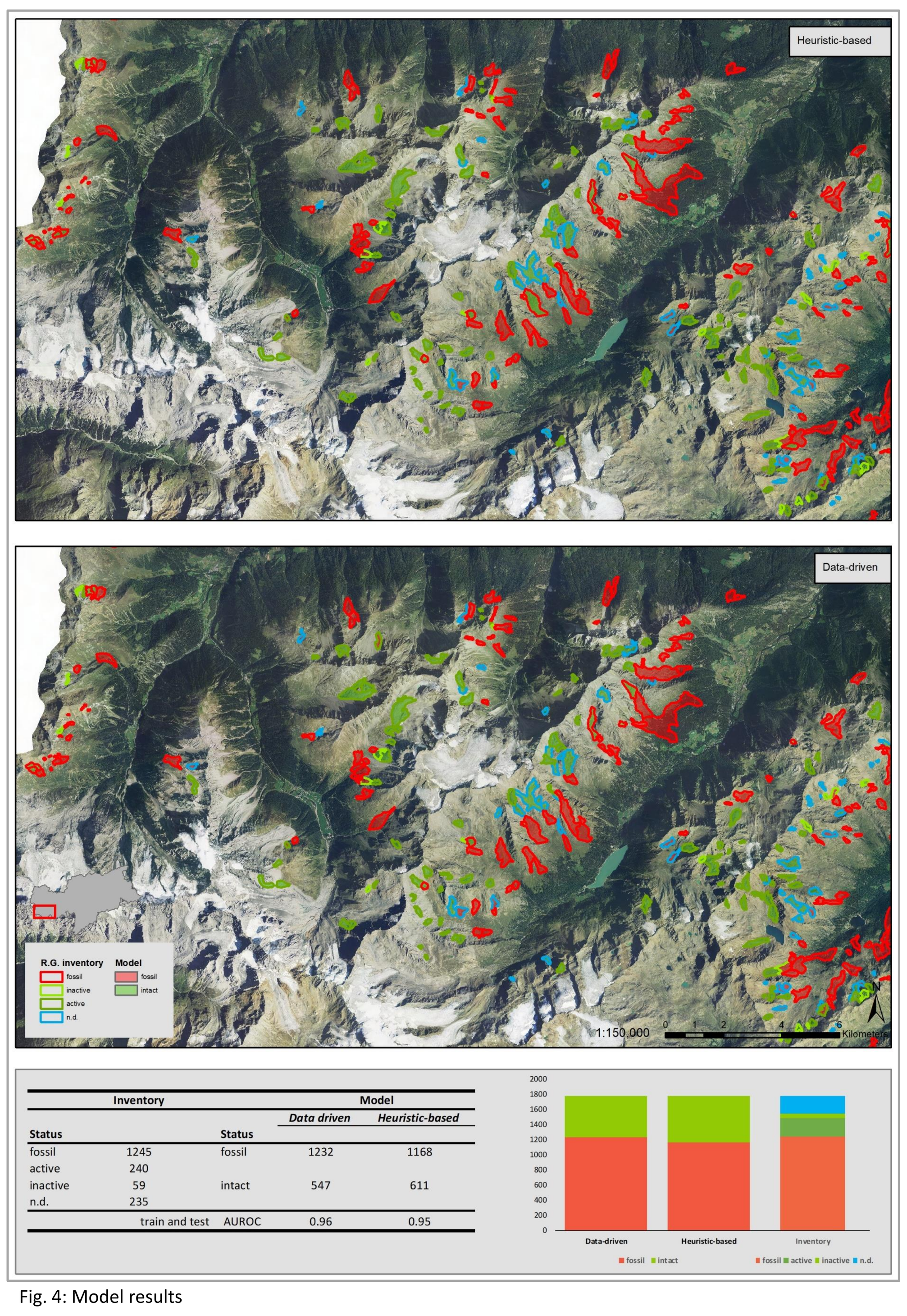


Fig. 4: Model results

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This research is kindly funded by Stiftung Südtiroler Sparkasse - Fondazione Cassa di Risparmio di Bolzano and Eurac Research

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