Design Project –SIE 2025

Rejuvenation of the Efflot de Veyges Rockfall Protection Forest

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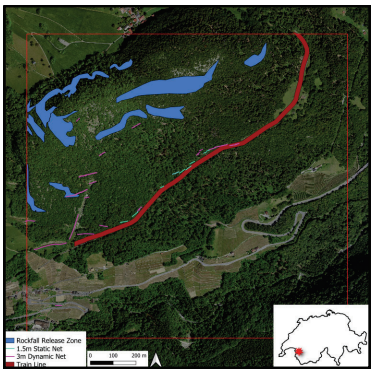
CONTEXT

In the European Alps, **rockfall** presents a persistent threat to settlements, infrastructure, and ecosystems. Rockfall protection forests (RPFs) offer a natural and cost-effective defense by reducing the **kinetic energy** and **runout distance** of falling rocks [1]. **Their effectiveness depends on forest structure, species composition, and regeneration**, all of which can be compromised by environmental stressors and disturbance events [2]. The **Efflot de Veyges forest near Aigle, Switzerland,** currently **protects a train line from rockfall,** but as an aging forest suffering from **wild ungulate grazing**, it requires a targeted rejuvenation strategy to restore its protective function without increasing rockfall risk during regeneration.



GOAL: maximum rejuvenation while maintaining rockfall protection

How will the Efflot de Veyges forest be rejuvenated?

The rejuvenation process consists of:

- adding **nets around a 10x10m area** to protect juvenile trees from being **grazed**
- **removing 30 % of canopy cover** to allow more light in the rejuvenation cells

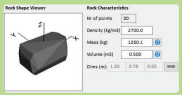
OBJECTIVES

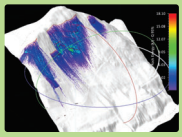
- Define the **optimal placement for rejuvenation cells** based on terrain characteristics and produce cell placement scenarios
- **Simulate rockfall events for each cell opening scenarios** and evaluate associated **rockfall hazards for the train line for a 30 year return period**
- Present **two rejuvenation cell strategies** and their i**mplementation protocol** for the next 90 years

METHODOLOGY

1.Identify **main terrain characteristics favorable for tree growth and survival.** Place rejuvenation cells and create cell opening scenarios every 30 years.

2. Simulate rockfall events on the software RAMMS::Rockfall. Provide input for **local terrain characteristics**: rockfall starting zones, forest density, terrain hardness, topography, protective nets and rock volume. And analyze model outputs: **rock trajectory, and kinetic energy.**





3. **Determine risk for damage on the train line** and propose **two cell opening protocols with associated risk statistics.** Define the cell placement for the next 90 years and provide **insightful data for cell placement opportunities on the hillslope.**

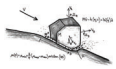
RESULTS

Simulation scenario	Max KE at trainline (kJ)	% increase in max KE	Danger category
No cells	290		Medium
Protection Year 0	265	-8,7172%	Medium
Protection Year 30	270	-6,7276%	Medium
Protection Year 60	318	9,8172%	High
Protection Year 90	307	5,8448%	High
Rejuvenation Year 0	291	0,3448%	Medium
Rejuvenation Year 30	347	19,6552%	High
Rejuvenation Year 60	401	38,2759%	High
Rejuvenation Year 90	504	73,7931%	High

CDN impact intensity categories for a 30 year return period:
Low = 0<KE<30 kJ
Medium = 30<KE<300 kJ
High = KE > 300 kJ

high intensity events on a 30 year return period

Hazards associated to the kinetic energy of rocks reaching the train line



highest % increase in rocks reaching the train line

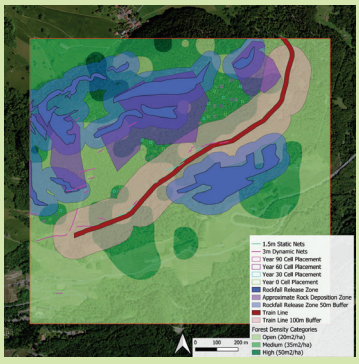
chance for a 500 L boulder to reach the train line once every 30 years

Simulation scenario	# rocks reaching train line	Increase in # rocks reaching train line	% increase in rocks reaching the train line	Reach probability
No cells	20			0,0222%
Protection Year 0	31	11	55,00%	0,0344%
Protection Year 30	23	3	15,00%	0,0256%
Protection Year 60	29	9	45,00%	0,0322%
Protection Year 90	32	12	60,00%	0,0356%
Rejuvenation Year 0	20	0	0,00%	0,0222%
Rejuvenation Year 30	27	7	35,00%	0,0300%
Rejuvenation Year 60	30	10	50,00%	0,0333%
Rejuvenation Year 90	28	8	40,00%	0,0311%

Hazards associated to the number of rocks reaching the train line

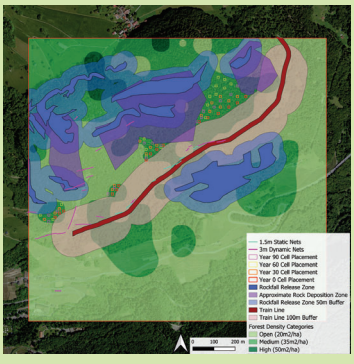
Protection-oriented scenario

- Opening of **8 cells** every 30 years
- Slighter increase in KE of rocks after opening
- Higher increase in rocks reaching the trainline



Rejuvenation-oriented scenario

- Opening of **16 cells** every 30 years
- Higher increase in KE of rocks after opening
- Lower increase in rocks reaching the trainline



CONCLUSION

- Opening rejuvenation cells **slightly increases reach probability** but **greatly increases maximum kinetic energy of rocks** traveling downhill
- Doubling the number of cells opened in preferred areas does not substantially increase reach probability
- Overall, reach probability increases from **1/4500** rocks reaching the train line to **1/2800** rocks after cell opening
- **5 cell opening scenarios out of 8 increase the hazard intensity category** (from Medium to High) of the area on a 30-year return period

These results will be used to **inform forest management decisions** to protect the train line running through the Efflot de Veyges forest from rockfall.

Sciences et ingénierie de l'environnement

Sources:
1. M. Brauner, W. Weinmeister, P. Agner, S. Vospernik, and B. Hoesle, "Forest management decision support for evaluating forest protection effects against rockfall," en, Forest Ecology and Management, vol. 207, no. 1-2, pp. 75–85, Mar. 2005, Number: 1-2, issn: 03781127. doi: 10.1016/j.foreco.2004.10.018.
2. E. Vangi et al., "Stand age diversity (and more than climate change) affects forests' resilience and stability, although unevenly," en, Journal of Environmental Management, vol. 366, p. 121 822, Aug. 2024, issn: 03014797. doi: 10.1016/j.jenvman.2024.121822.