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Disturbance impacts on protective forests in mountain areas – current knowledge and future research directions

Michaela Teich

2nd Alpine Workshop on
Fire-induced geohydrological processes in mountainous areas

BOKU University, Vienna

25 April 2025

Protective forests are…

(1,2,3) snow avalanches
(4) rockfall
(5) floods and debris flows
(6) landslides

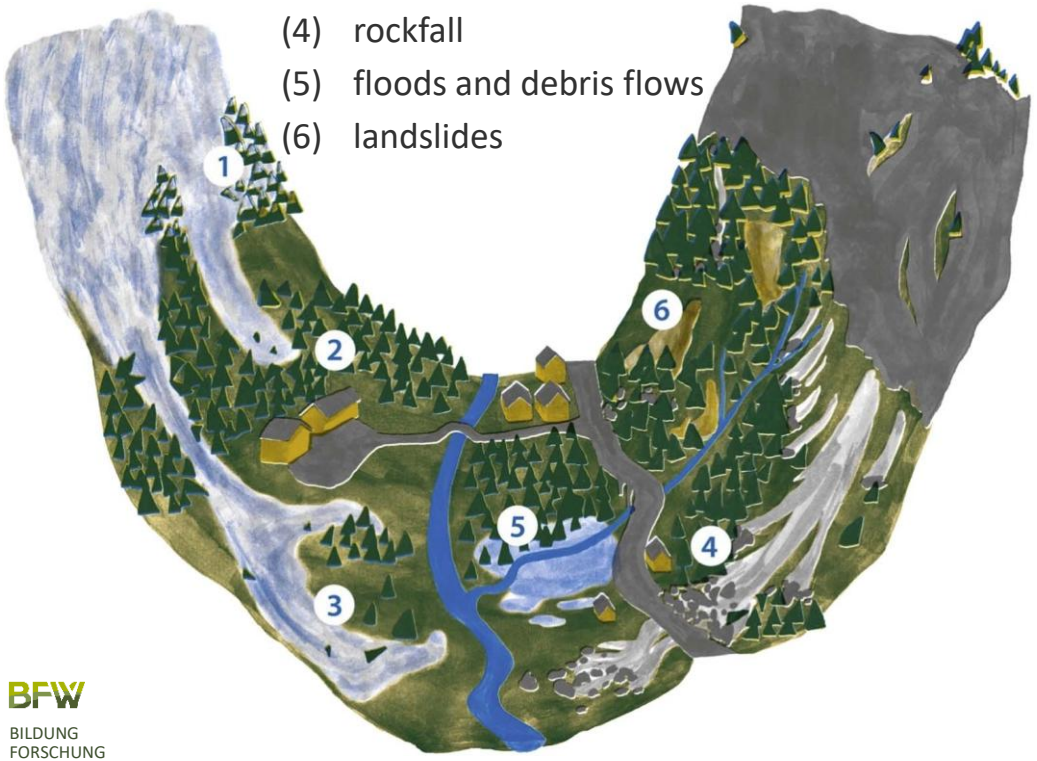

Figure: Moos et al. 2018

"A protective [protection] forest is a forest that has as its primary function the protection of people or assets against the impacts of natural hazards or adverse climate."

Brang et al. 2001

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Forests‘ protective functions and effects

How does a forest protect?

PROTECTIVE EFFECT

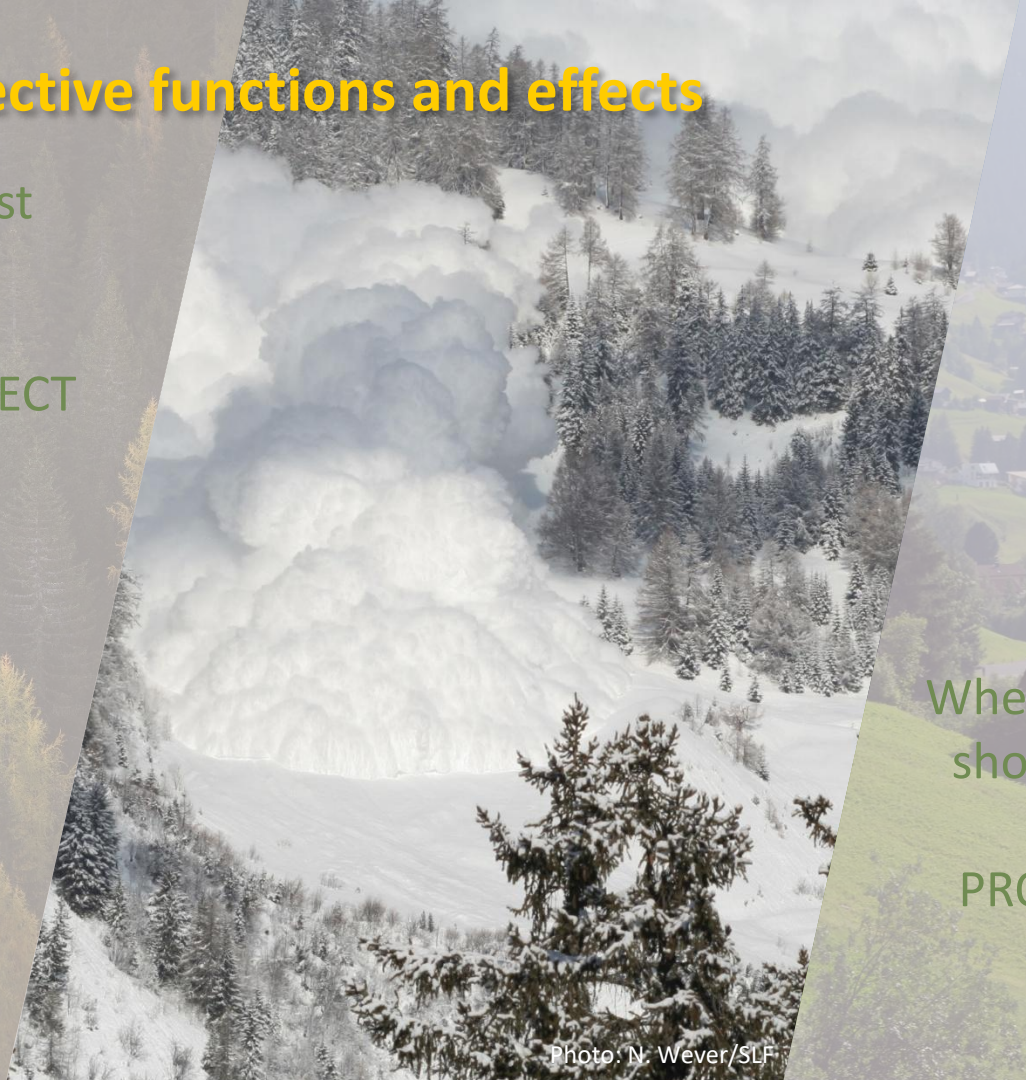


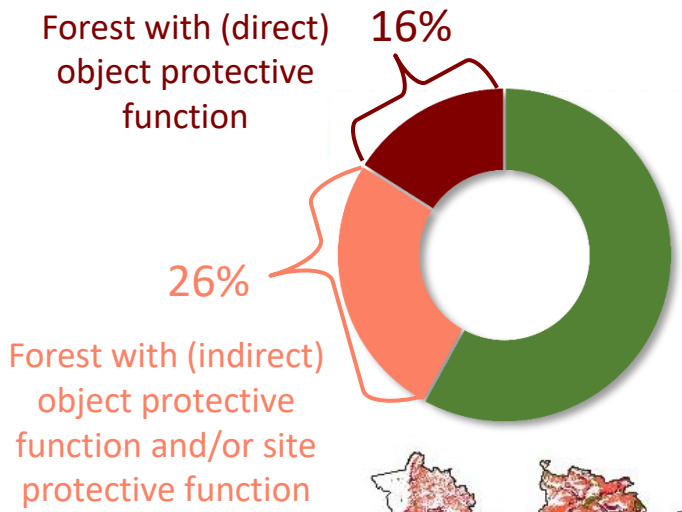
Photo: N. Wever/SLF

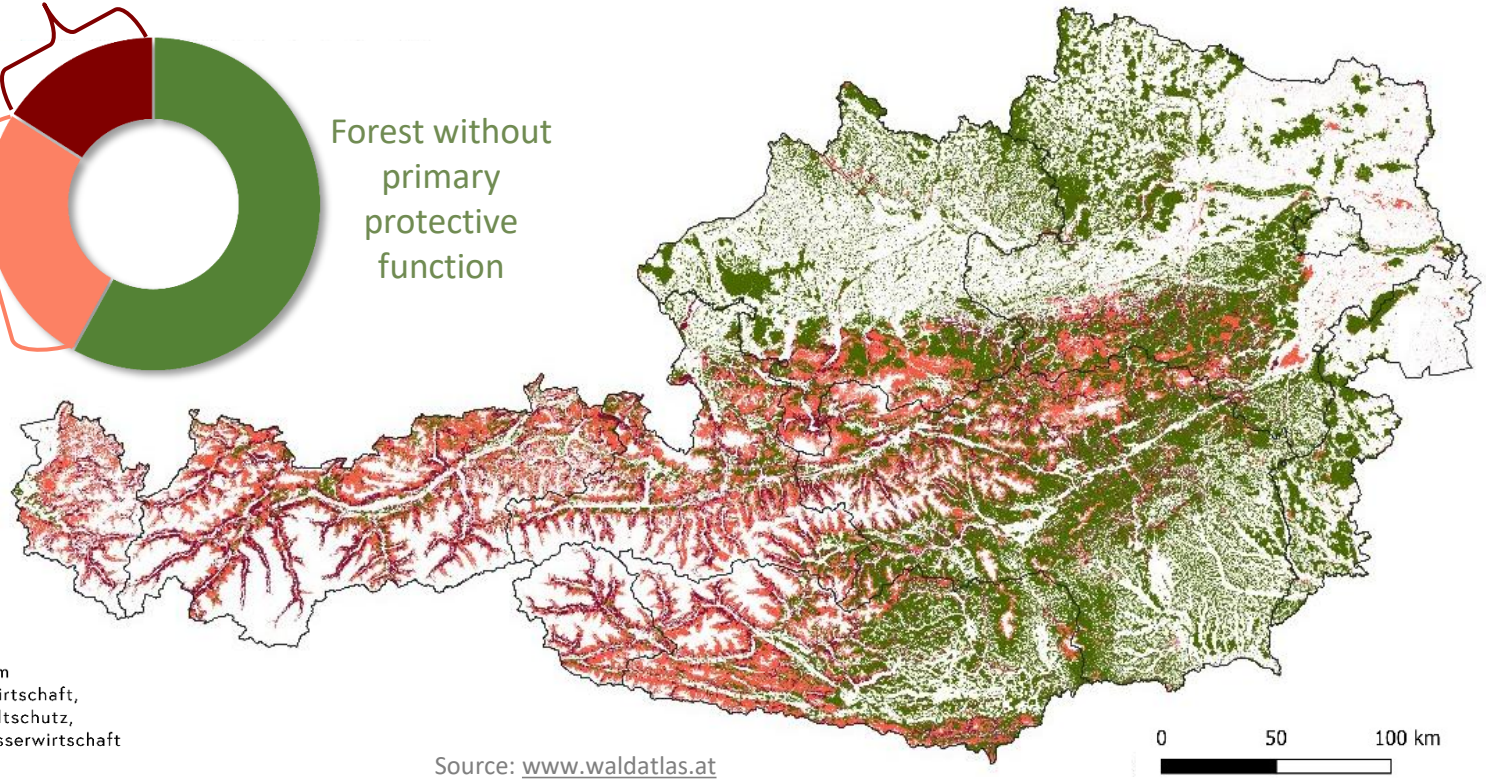
Where, What and Whom should a forest protect?

PROTECTIVE FUNCTION

Protective forest cover in Austria

42% potential protective forest area
(based on scientific criteria)





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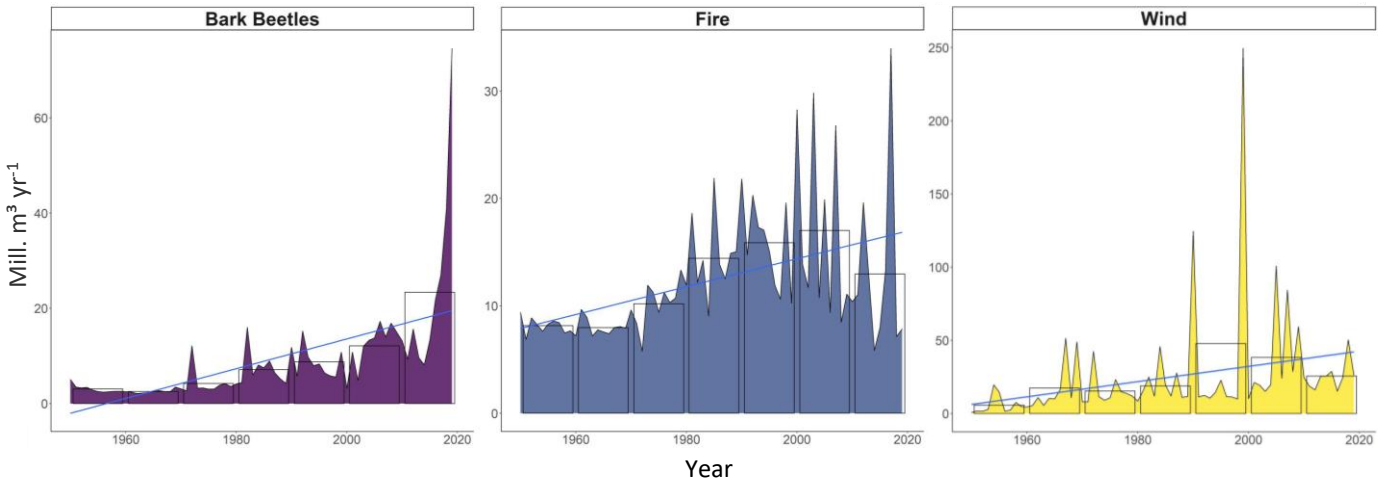
Land- und Forstwirtschaft,
Klima- und Umweltschutz,
Regionen und Wasserwirtschaft

Source: www.waldatlas.at

Protective forests are under pressure



Expert's interpreted gap-filled time-series of disturbance drivers in Europe between 1950 and 2019.

34 European countries:

- increase in all drivers of natural disturbances
- largest increase: bark beetles – their impact has doubled over the past 20 years

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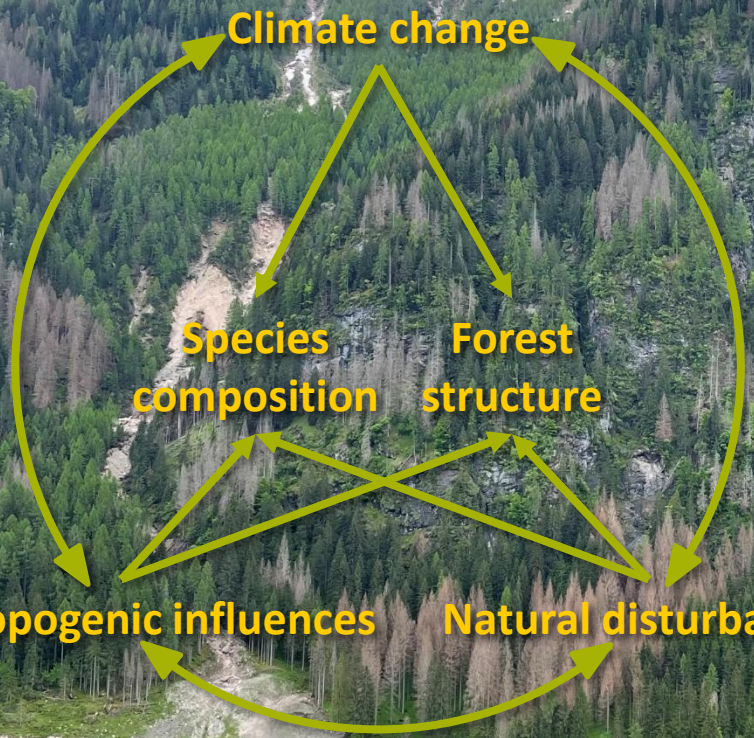
Patacca et al. 2022

Protective forests are under pressure



Global change impacts on PROTECTIVE EFFECTS: what does science say?

Veneto region, Italy; 05/2024

Illustration adapted from: Bottero al. 2024

Photo: M. Teich

Global change impacts on protective forests: what does science say?

frontiers | Frontiers in Forest and Global Change

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Mountain protective forests under threat? an in-depth review of global change impacts on their protective effect against natural hazards

Christine Moos[1]*, Ana Stritih[2], Michaela Teich[3] and Alessandra Bottero[4,5]

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Global change impacts on protective forests: what does science say?

Literature search

Clarivate Web of Science™ | CABI | Google Scholar

Protective forest	forest* OR “protection forest” OR “ forest” OR “Eco-DRR”
Global change	"cli ge" OR "global change" OR change OR drought OR disturbance OR future OR evolution OR "forest dynamics" OR “ecosystem dynamics” OR “dynamic” OR development*
Protective service	"natural hazard" OR "risk reduction" OR "protective effect" OR “ function” OR "protection function" OR "protective capacity" OR avalanche OR landslide OR flood OR rockfall OR “peak flow” OR “debris flow”

Forest change:
- climate-induced
- (changing) natural disturbance
- anthropogenic-driven (e.g., land-use change, management interventions)

Natural hazards:
- torrential floods
- debris flows
- snow avalanches
- rockfall
- shallow landslides

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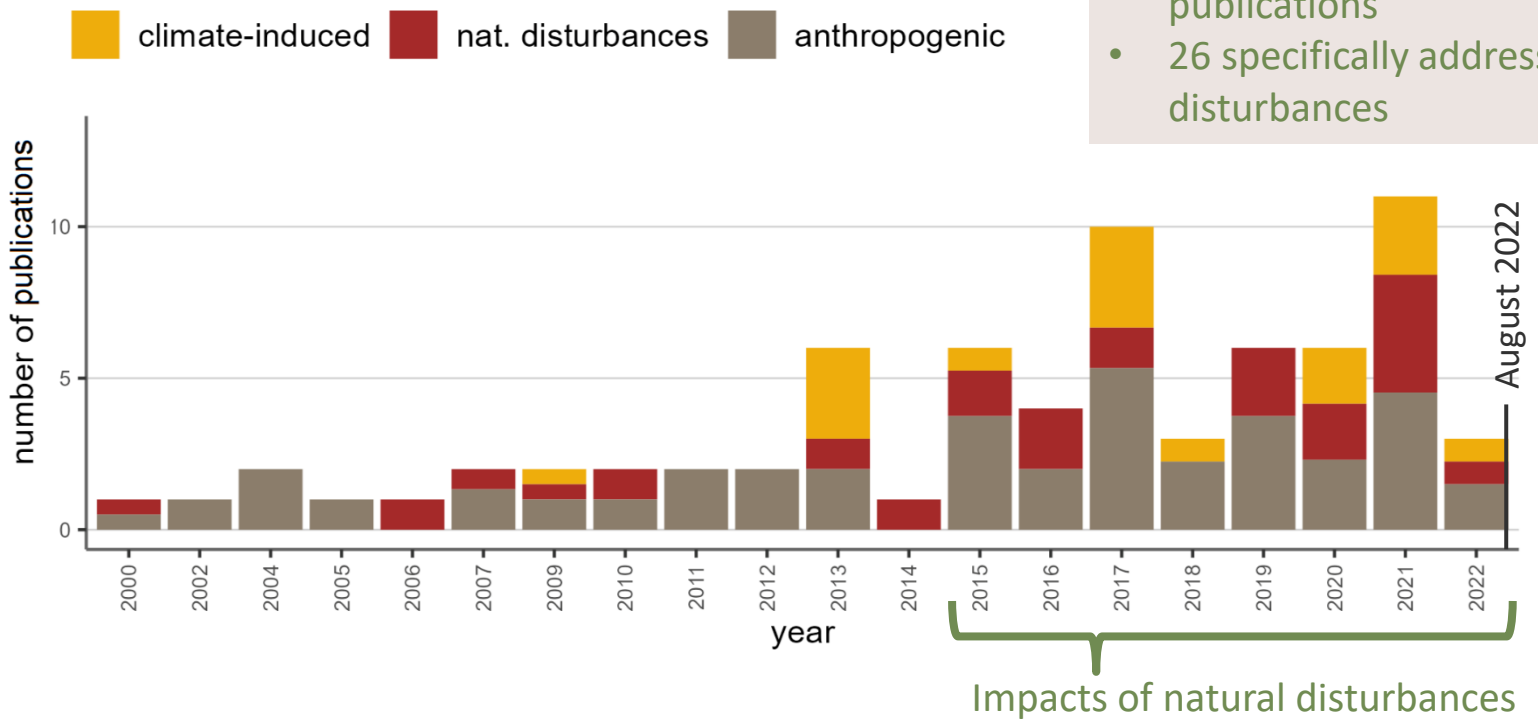
Global change impacts on protective forests: what does science say?

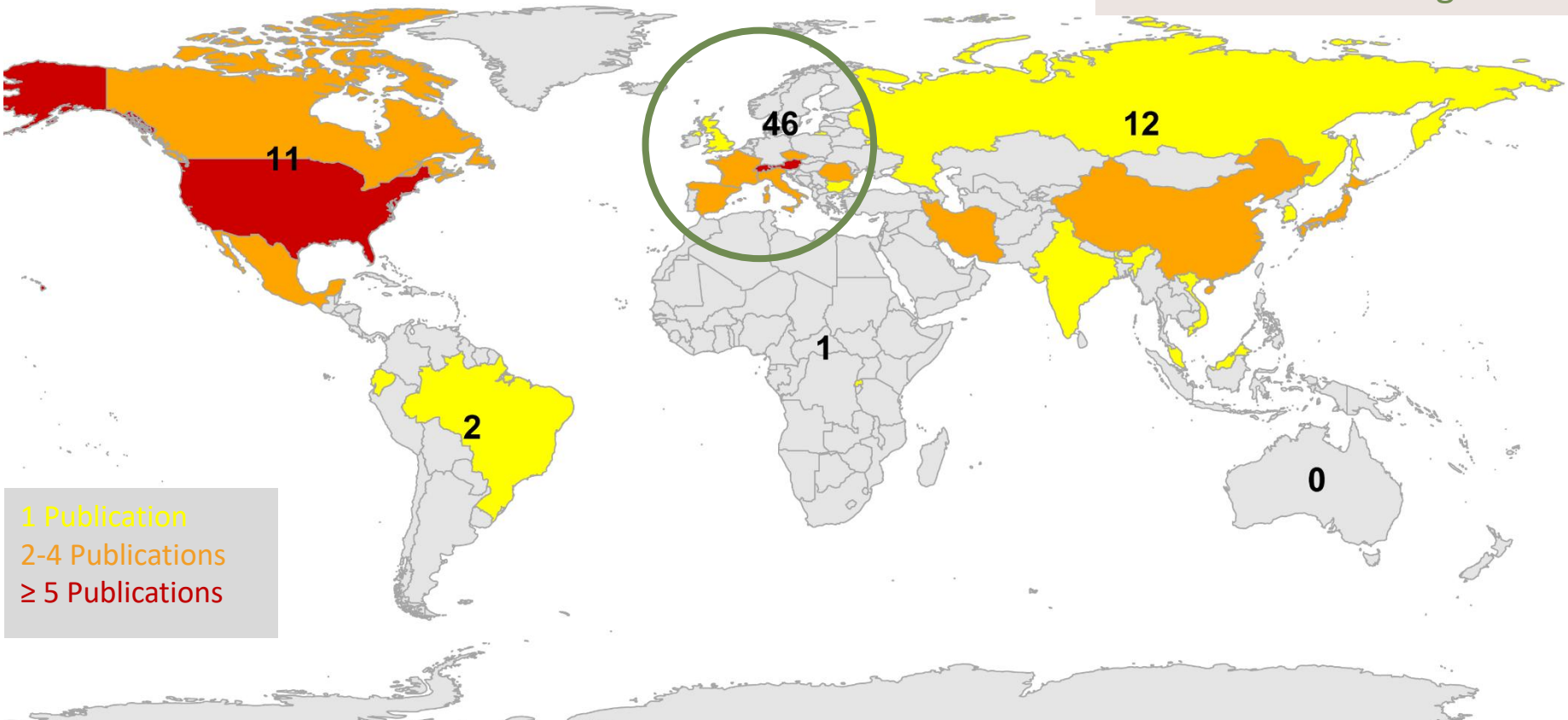
Not that much.

- 72 peer-reviewed English publications
- 26 specifically addressed disturbances

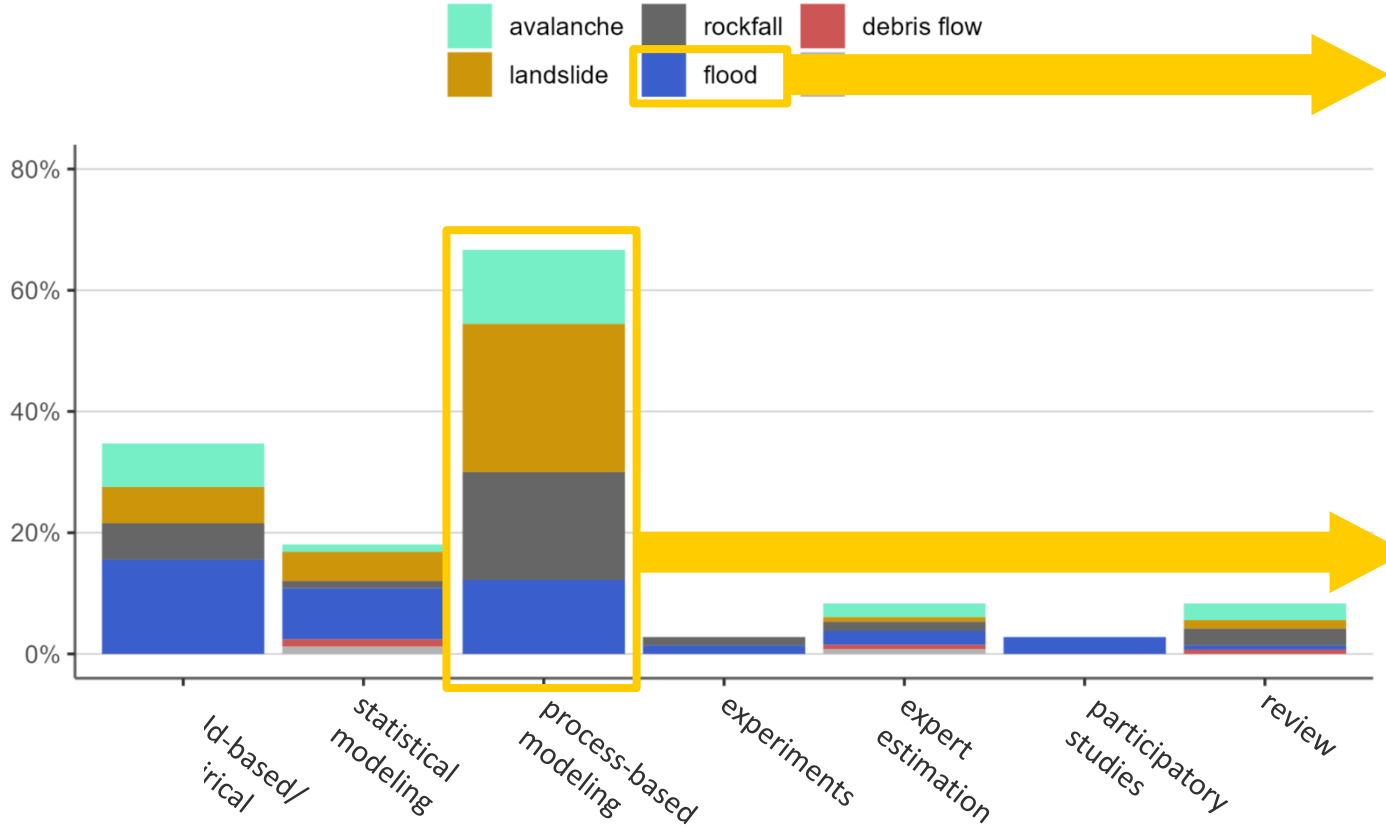


Global change impacts on protective forests: what does science say?

The research is not global.



Global change impacts on protective forests: what does science say?



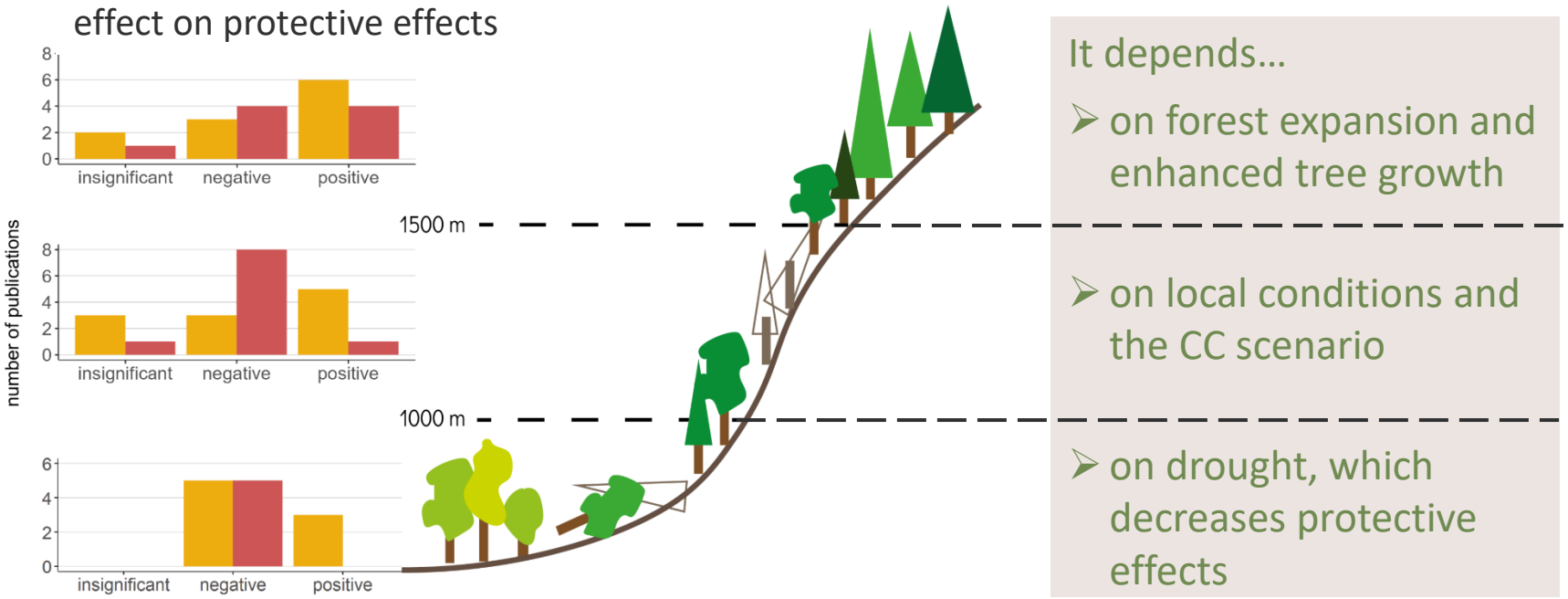
Natural hazards:

- 43% floods
- 33% rockfall, landslides and/or snow avalanches
- only 2 studies on debris flows

Methods:

- process-based modeling
- only 15% accounting for risk

Climate-induced forest change: what does science say?



It depends…

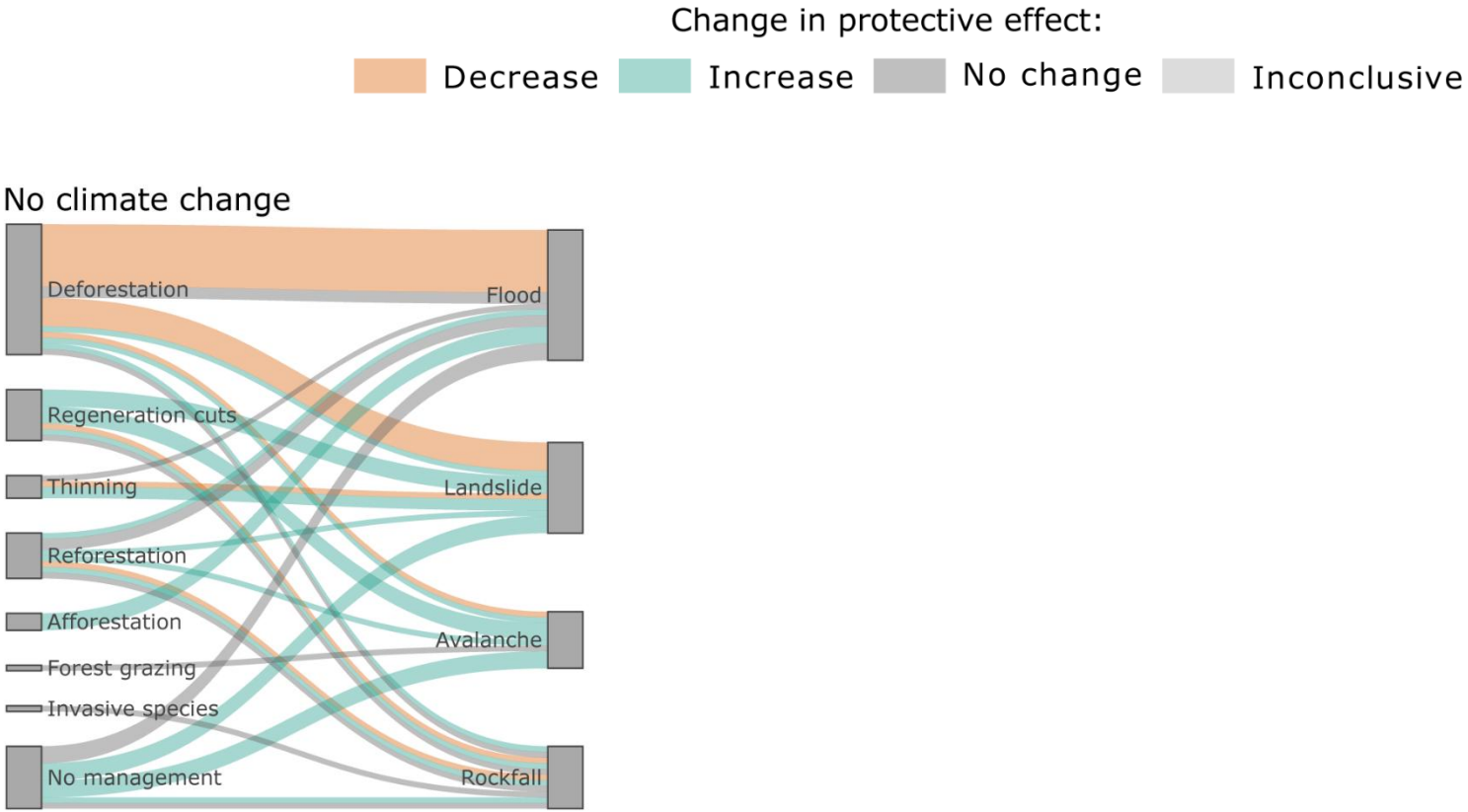
- on forest expansion and enhanced tree growth
- on local conditions and the CC scenario
- on drought, which decreases protective effects

climate change (CC)

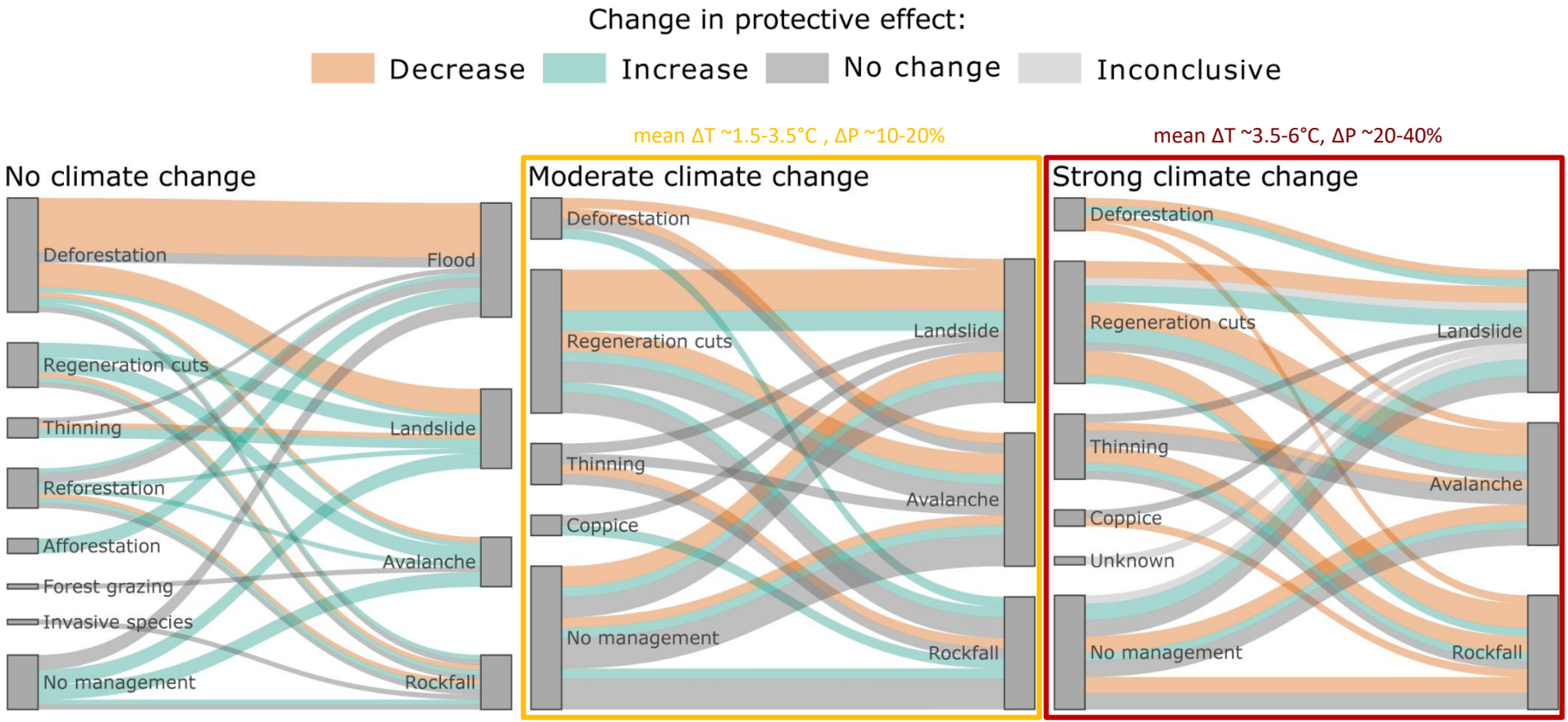
- moderate: mean air temperature increase of ~1.5-3.5°C; no or a slight precipitation decrease of ~10-20%
- strong: mean air temperature increase of ~3.5-6°C; significant precipitation decrease of ~20-40%.

Increasing natural disturbances counter-balance effects of enhanced tree growth!

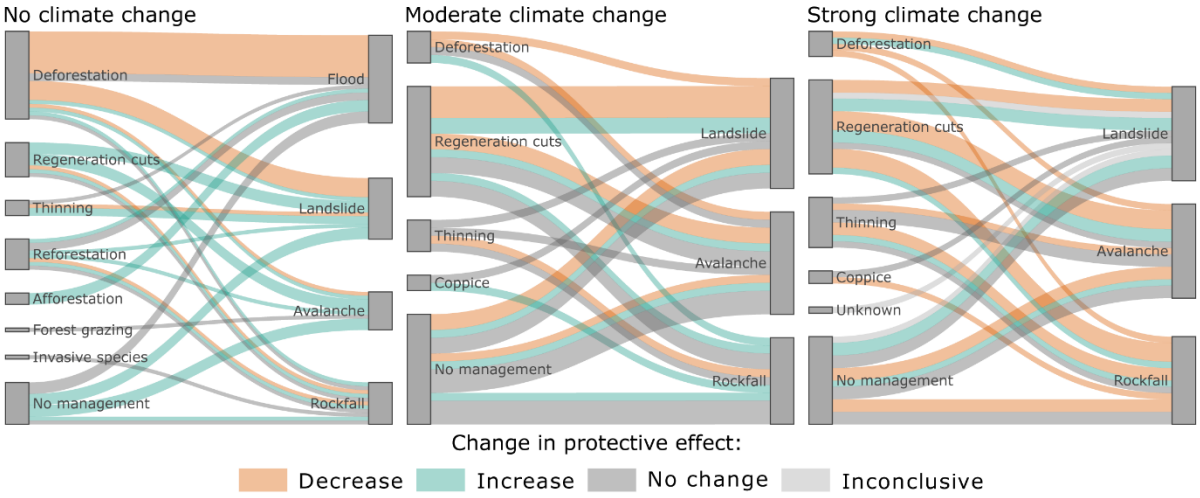
Anthropogenic-driven forest change: what does science say?



Anthropogenic-driven forest change: what does science say?



Anthropogenic-driven forest change: what does science say?



It's not a clear-cut picture.

- deforestation generally has negative impacts
- strongly dependent on CC scenario
- e.g., no management and no climate change increase protective effects, but effect decreases under CC
- e.g., negative effects of regeneration cuts and thinning increase under CC scenarios

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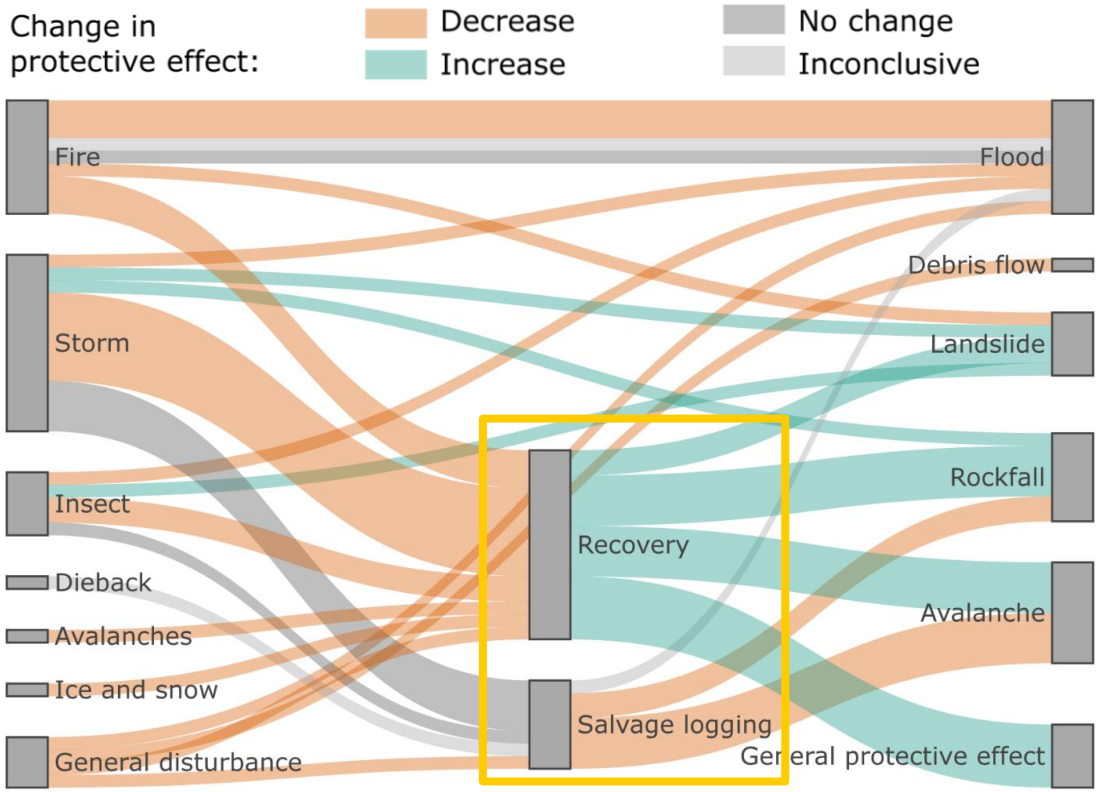
Interactions between CC and anthropogenic influences are complex.

Natural disturbances: what does science say?



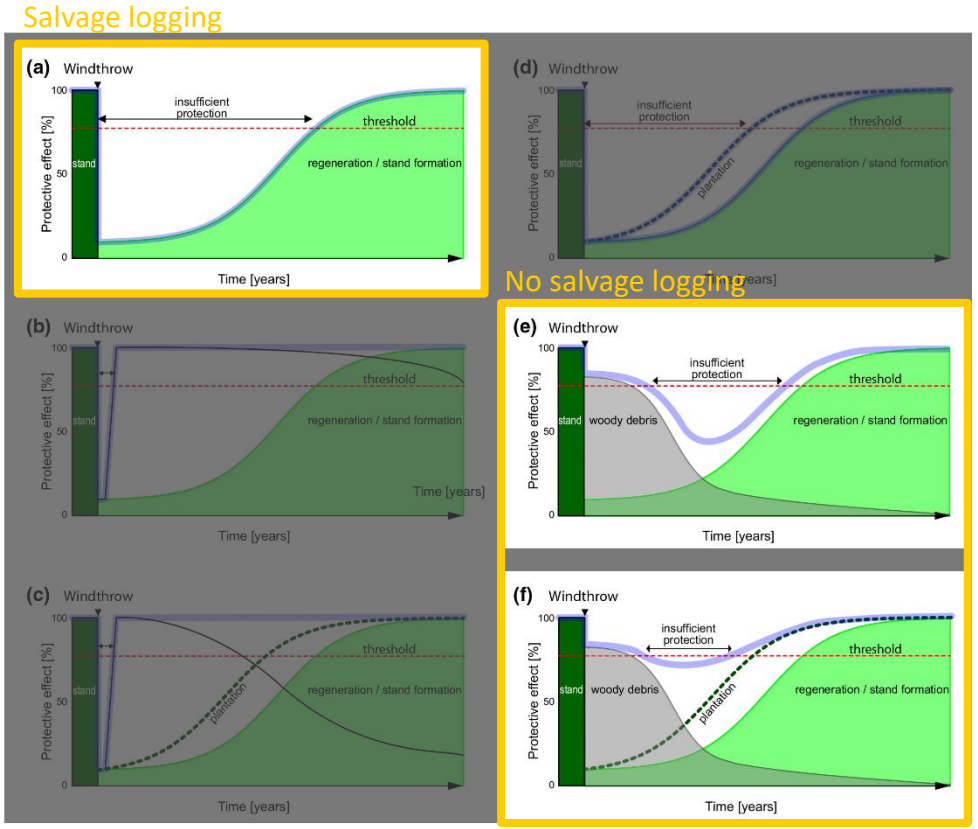
26 publications:

- 11 studies focus on forest fire (torrential floods)
- often decrease protective effects dependent on severity
- but severity was often not addressed

Post-disturbance management is key.

Post-windthrow management: protection gap

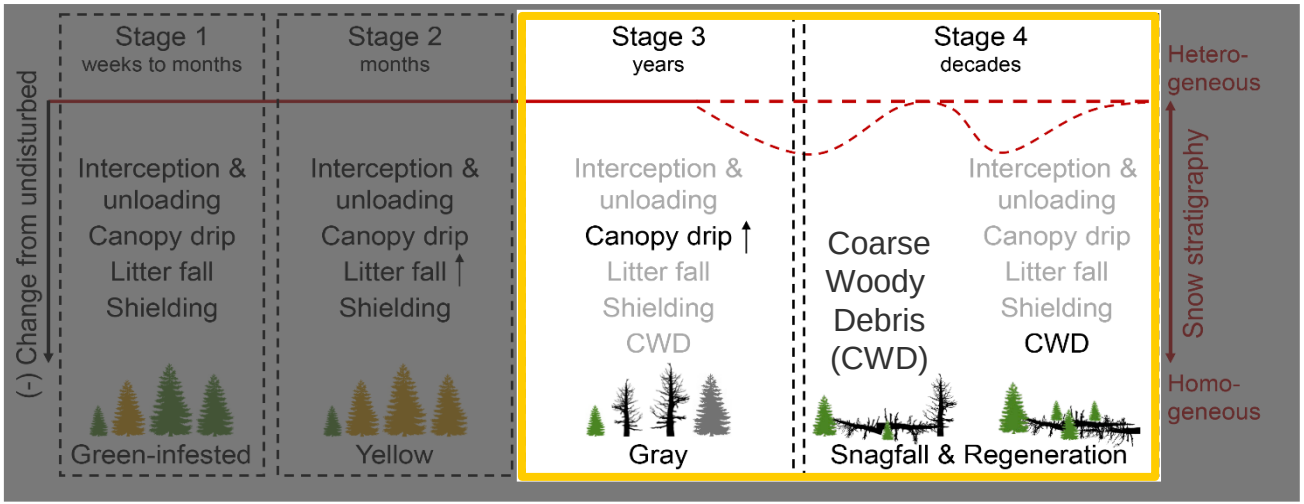
- Lying stems provide a considerable protective effect against snow avalanches and rockfall,
- which decreases over time towards a presumed critical stage.
- Tree regeneration increasingly replaces the protective effect of woody debris,
- but the regeneration process is often too slow.



Schematic development of the protective effect in windthrow areas of mountain forests after different treatments

Wohlgemuth et al. 2017

Post-bark beetle management: protection gap

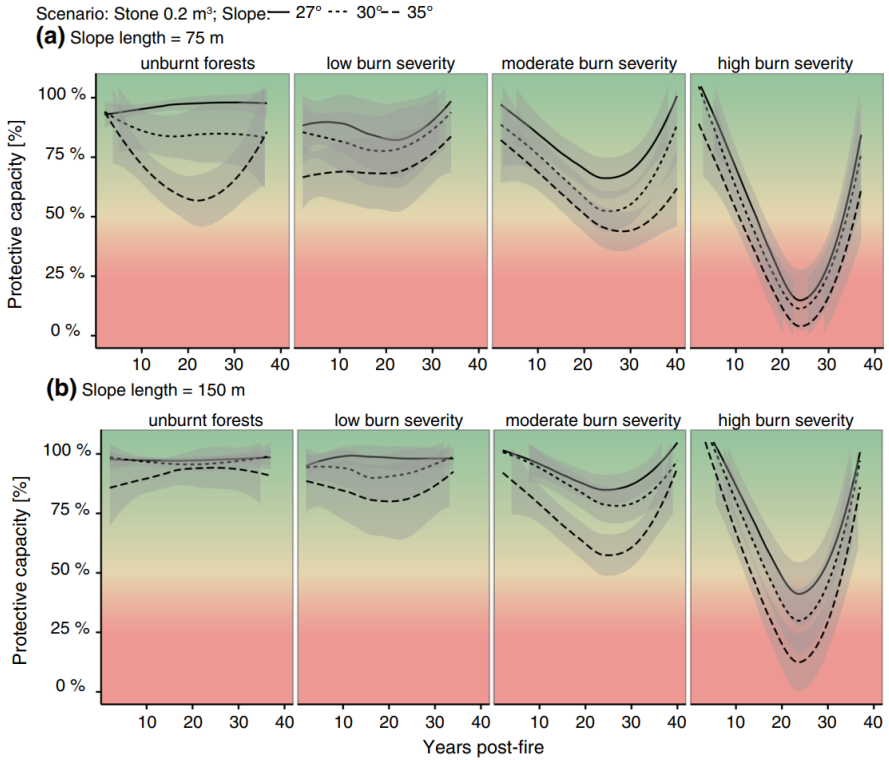


Conceptual model of changes to the spatial variability in snow stratigraphy that are linked to avalanche formation following bark beetle outbreak

Teich et al. 2019

Post-fire management: protection gap

- Standing or fallen dead trees provide seeds, shade, moisture and nutrients to the regeneration, and
- contribute temporally to the protection against rockfall, especially in low-severity burns.
- Moderate-to-high severe fires may lead to temporary deficits in the protective effect,
- depending on the effective burn severity, rock sizes, length and mean inclination of the forested slope.



Trends in the protective effect (%) of beech stands in different-severity burns and unburnt beech forests against intermediate-sized rocks (0.2 m^3)

Maringer et al. 2016

Future research directions?

Closing the gaps.

Protective effect of windthrow areas against snow avalanches

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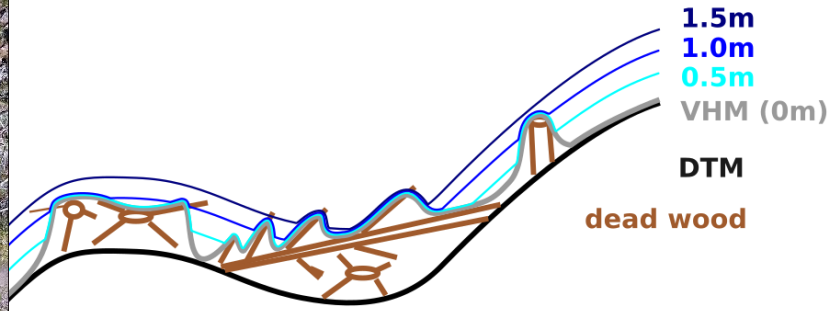
Which protective effect has a windthrow area, if „filled“ with snow?



Bührle et al. 2025

Protective effect of windthrow areas against snow avalanches

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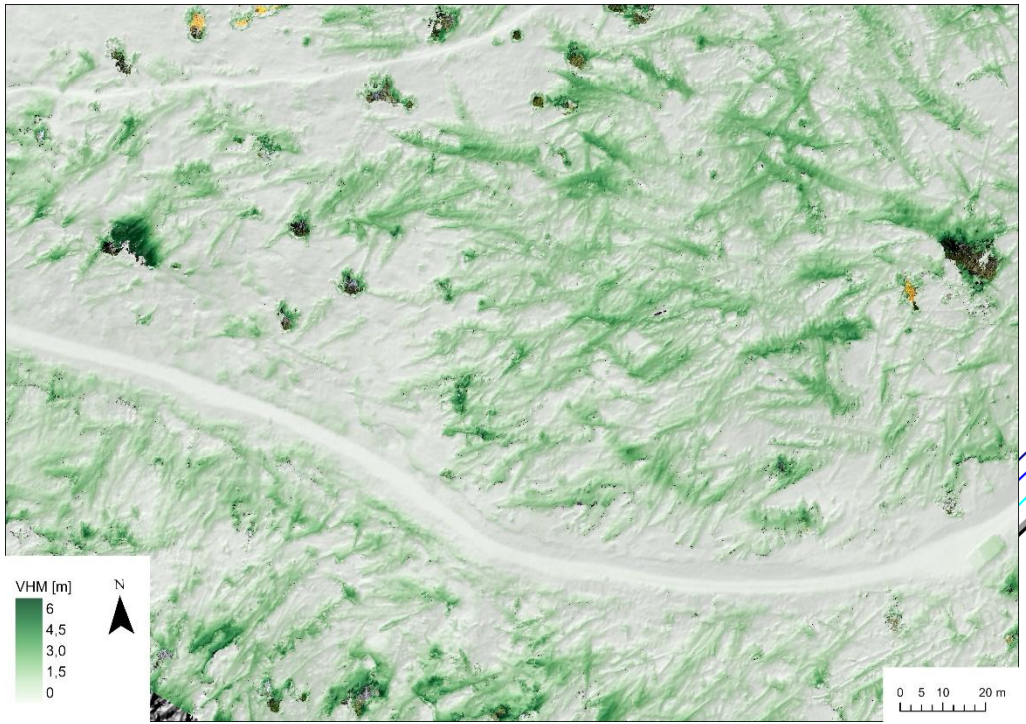
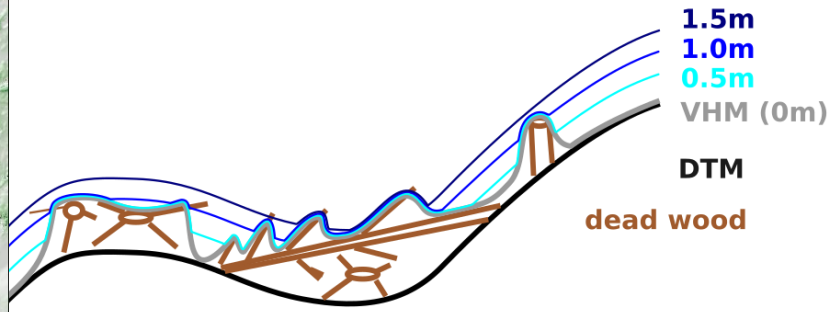


- Vegetation height model (VHM) from drone photogrammetry



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Protective effect of windthrow areas against snow avalanches

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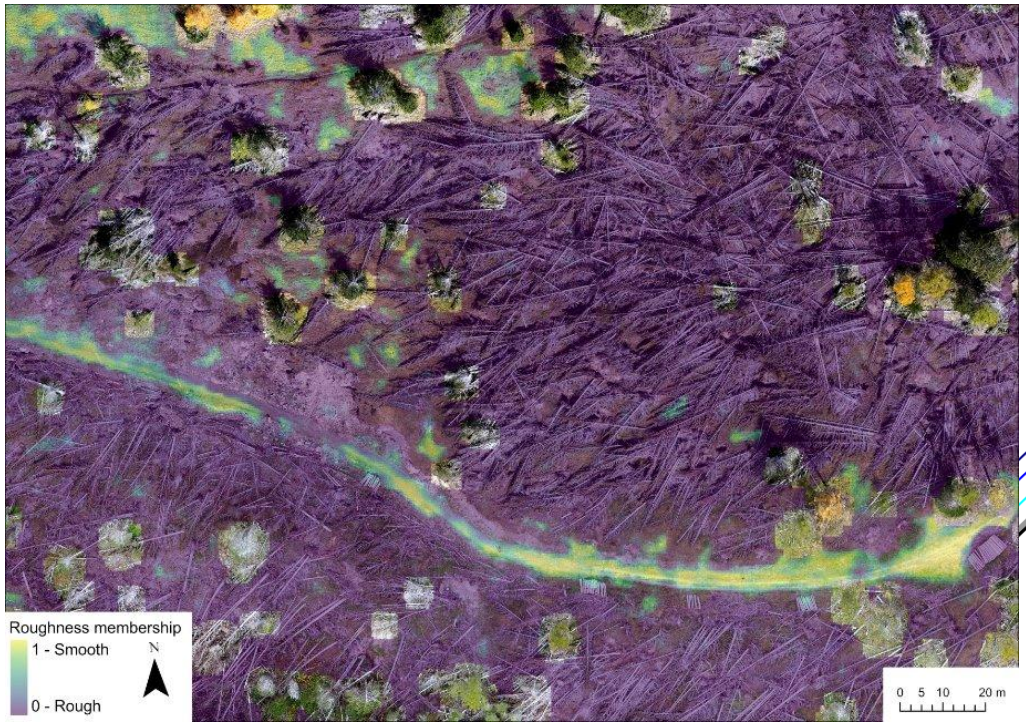
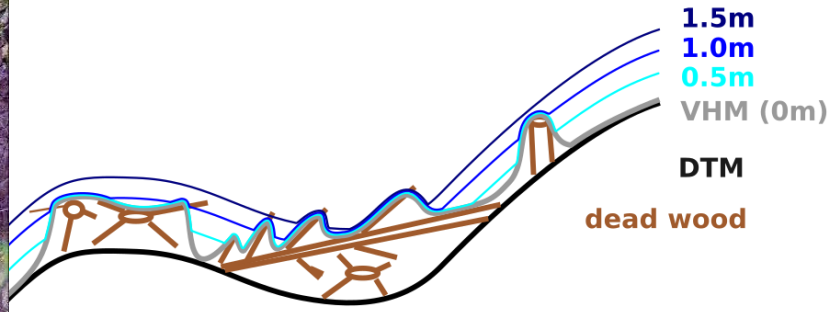


- Roughness membership (no snow)



Bührle et al. 2025

Protective effect of windthrow areas against snow avalanches

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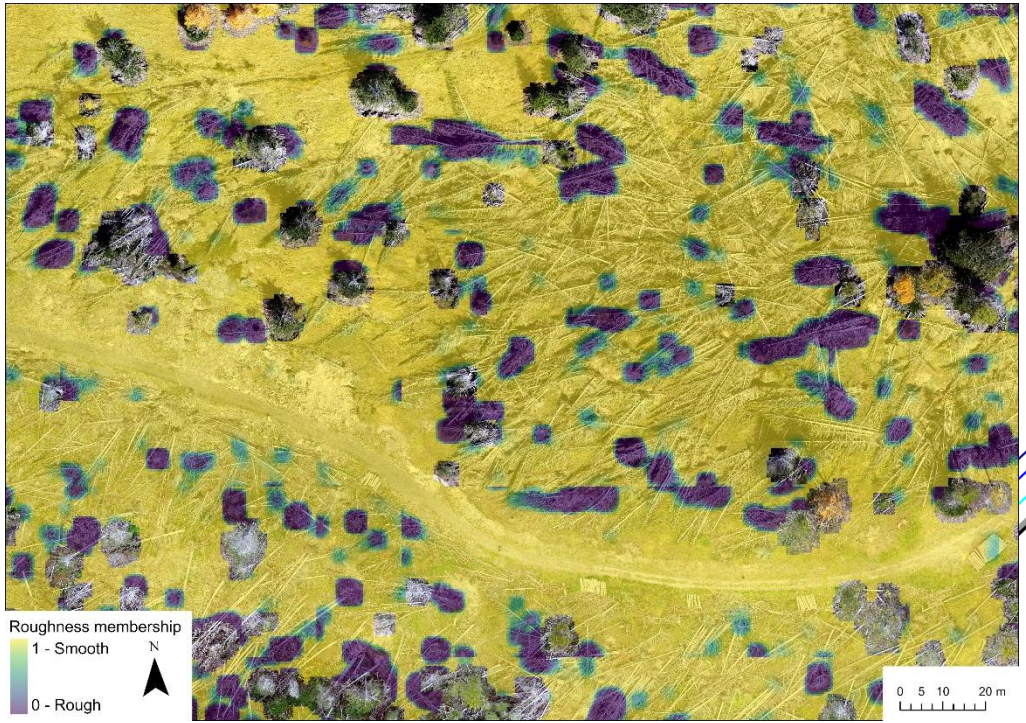
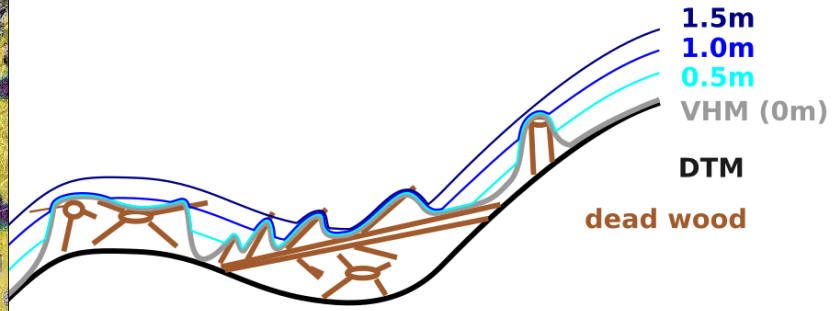


- Roughness membership (1,5 m snow depth ≈ 10-year return period)



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Protective effect of windthrow areas against snow avalanches

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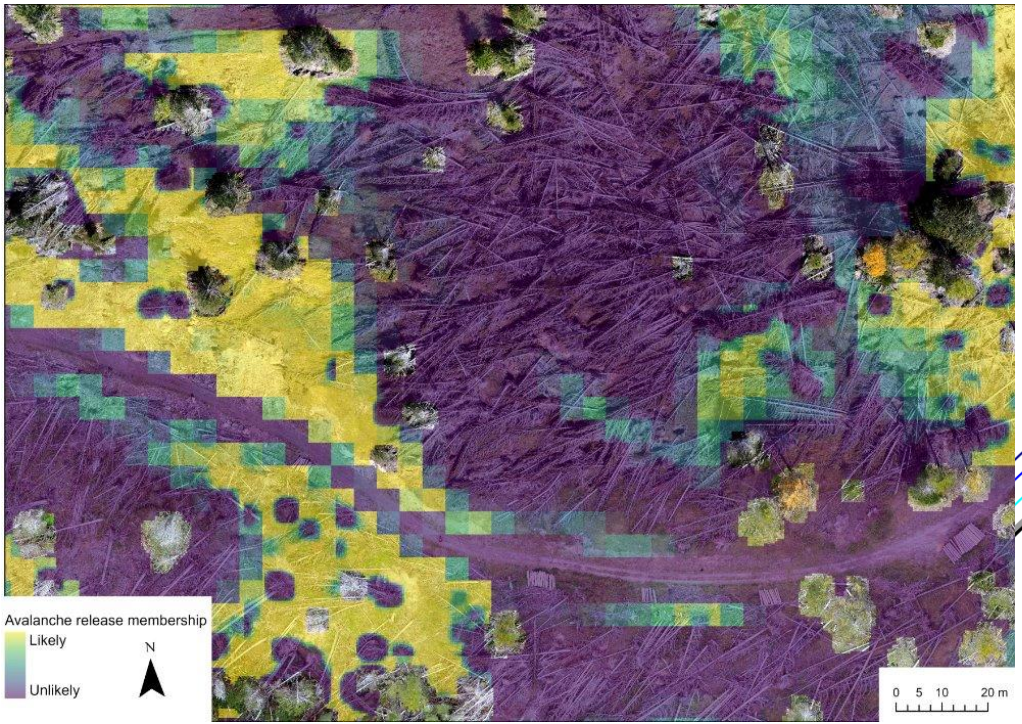
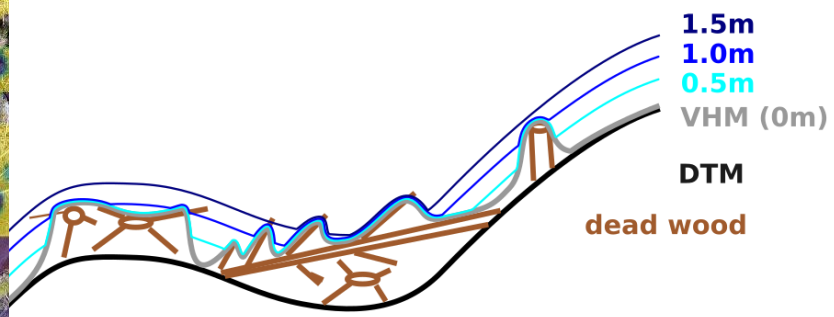


- Avalanche release membership / probability (1,5 m snow depth ≈ 10-year return period)



Bührle et al. 2025

Post-fire recovery in protective forests

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Drivers of post-wildfire regeneration and impacts on forests' protective effects?

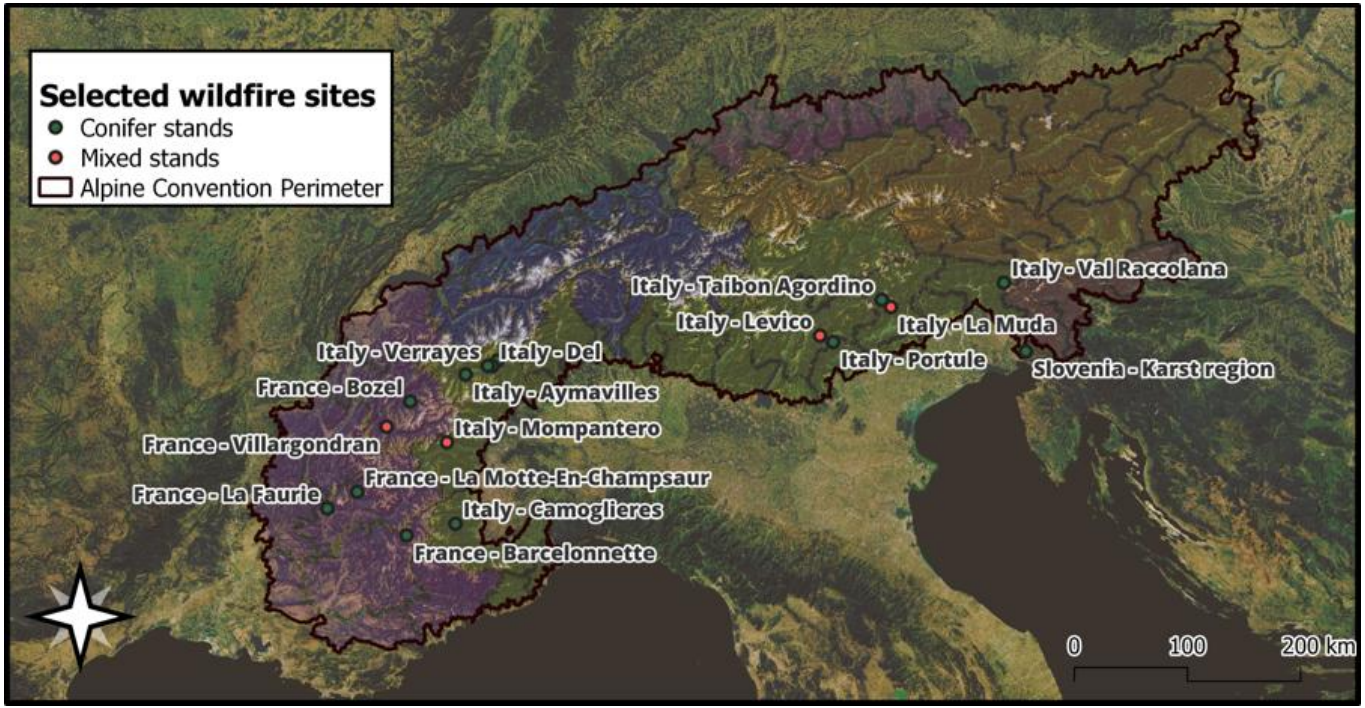

Figure: Nicolò Anselmetto

If you have and would like to share post-wildfire regeneration data, please contact us!

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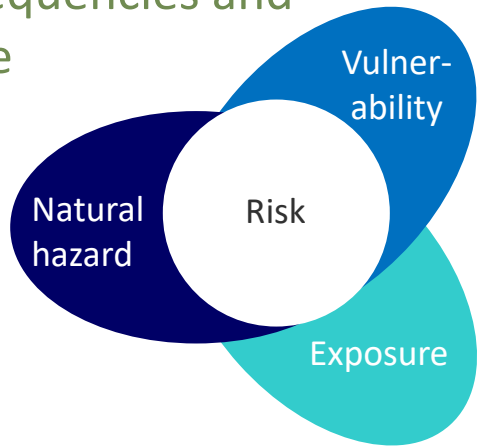
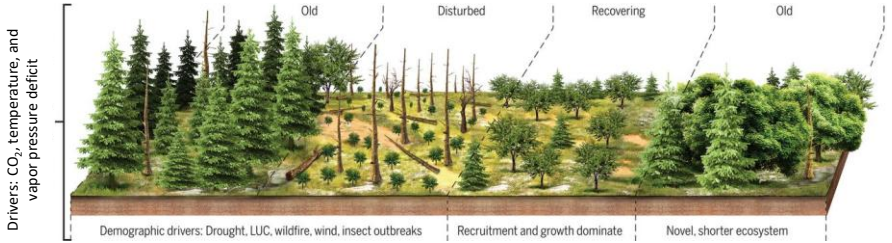
Take home messages

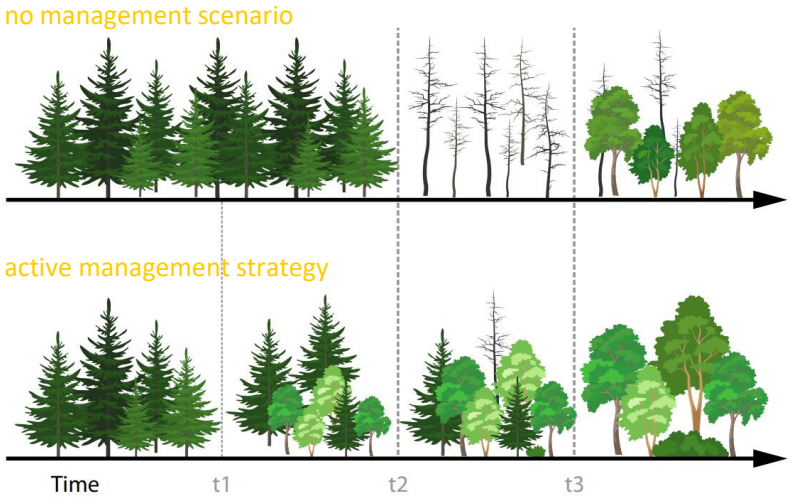
- forests change constantly
  - global change and especially disturbances determine and accelerate forest pathways
  - as do management decisions
- natural hazard frequencies and intensities change
- society changes



Conceptual diagram of the components of forest dynamics and the disturbances that drive them



Possible pathways of forest development under climate change



Figures: McDowell et al. 2020; Jandl et al., 2019

References

Bottero, A., Moos, C., Stritih, A., Teich, M. (2024). Editorial: Impacts of global change on protective forests in mountain areas. Frontiers in Forests and Global Change, 7, 1375285. https://doi.org/10.3389/ffgc.2024.1375285

Brang, P., Schönenberger, W., Ott, E., Gardner, B. (2001). Forests as Protection from Natural Hazards. In: Evans J, editor. The Forests Handbook: Applying Forest Science for Sustainable Management 2. Oxford: Blackwell Science; 2001. p. 53–81.

Bührle, L., Baggio, T., Adams, M., Winiwarter, L., Lingua, E., Stoffel, A., Marke, T., Bebi, P., Teich, M. (2025). Assessment of protective effect of wind-disturbed forest against snow avalanches. EGU General Assembly 2025, Vienna, Austria, 27 Apr–2 May 2025, EGU25-17290. https://doi.org/10.5194/egusphere-egu25-17290

Jandl, R., Spathelf, P., Bolte, A., Prescott, C.E. (2019). Forest adaptation to climate change—is non-management an option? Annals of Forest Science, 76, 48. https://doi.org/10.1007/s13595-019-0827-x

Maringer, J., Ascoli, D., Dorren, L., Bebi, P., Conedera, M. (2016). Temporal trends in the protective capacity of burnt beech forests (Fagus sylvatica L.) against rockfall. European Journal of Forest Research, 135, 657-673. https://doi.org/10.1007/s10342-016-0962-y

McDowell, N. G., Allen, C. D., Anderson-Teixeira, K., Aukema, B. H., Bond-Lamberty, B., Chini, L., ... & Xu, C. (2020). Pervasive shifts in forest dynamics in a changing world. Science, 368(6494), eaaz9463. https://doi.org/10.1126/science.aaz9463

Moos, C., Bebi, P., Schwarz, M., Stoffel, M., Sudmeier-Rieux, K., Dorren, L. (2018). Ecosystem-based disaster risk reduction in mountains. Earth-Science Rev., 177, 497–513. https://doi.org/10.1016/j.earscirev.2017.12.011

Moos, C., Stritih, A., Teich, M., Bottero, A. (2023). Mountain protective forests under threat? an in-depth review of global change impacts on their protective effect against natural hazards. Frontiers in Forests and Global Change, 6:1223934. https://doi.org/10.3389/ffgc.2023.1223934

Teich, M., Giunta, A. D., Hagenmuller, P., Bebi, P., Schneebeli, M., Jenkins, M. J. (2019). Effects of bark beetle attacks on forest snowpack and avalanche formation – Implications for protection forest management. Forest Ecology and Management, 438, 186–203. https://doi.org/10.1016/j.foreco.2019.01.052

Wohlgemuth, T., Schwitter, R., Bebi, P., Sutter, F., Brang, P. (2017). Post-windthrow management in protection forests of the Swiss Alps. European Journal of Forest Research, 136(5–6), 1029–1040. https://doi.org/10.1007/s10342-017-1031-x

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Thank you for listening!

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