

# Modelling the effect of Nature Based Solutions on slope instability

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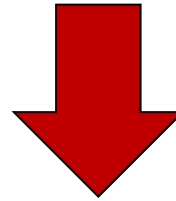
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# Study area

**Nature-Based Solutions** (NBS - *Cohen-Shacham et al.*, 2016) are solutions that are inspired and supported by nature to reduce specific hydro-meteorological risks. The OPERANDUM (EU-H2020) project's main aim is to develop and model these solutions in **specific sites** (Open Air Laboratories - **OAL**).



The OAL-Austria is located in Vögelsberg (Tyrol, Austria). It is characterized by a **deep-seated gravitational slope deformation (DSGSD)**, which has recently shown active movements.

The area is subject to the following natural hazards:

- Deep-seated deformation due to gravitational load
- Deep-seated landslide.
- Secondary slope failures and debris flows on the footslope.

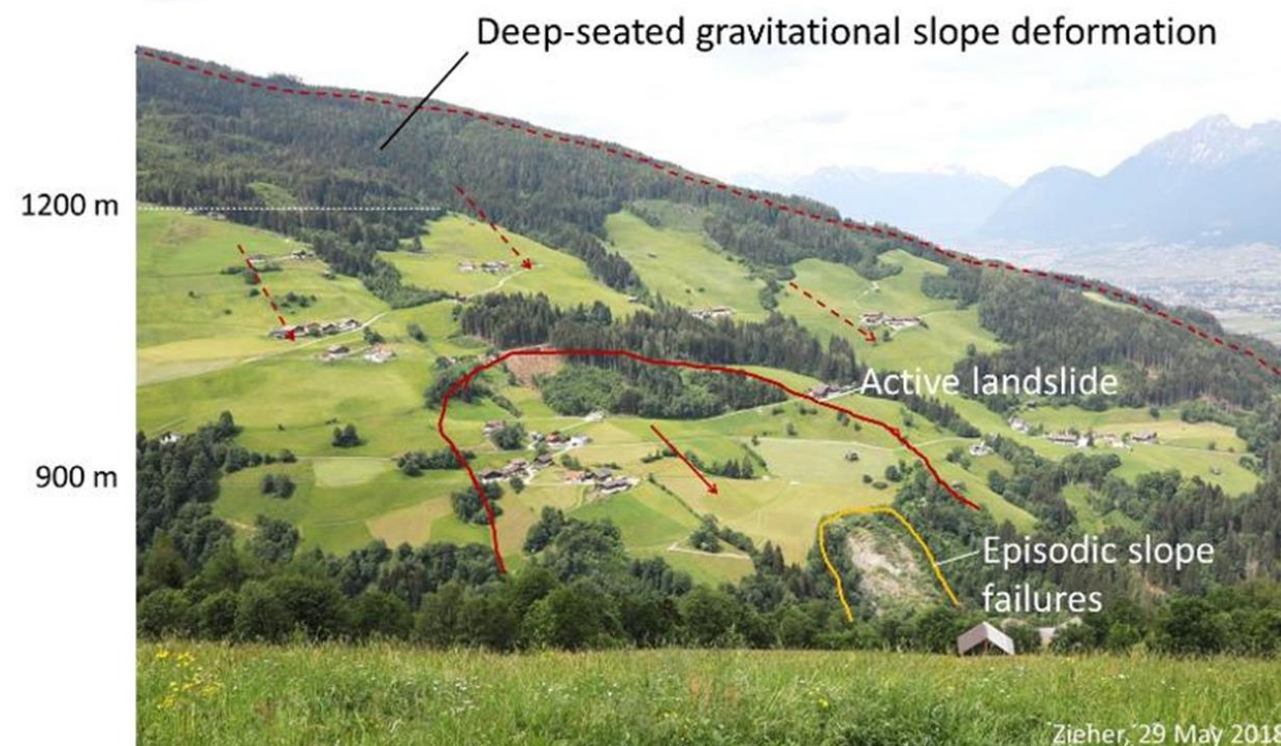
# Study area

The whole OAL covers an area of about  $5 \text{ km}^2$ , ranging from 750 m to 2000 m a.s.l., with a **currently active part** of  $0,25 \text{ km}^2$ .

An efficient **local monitoring activity** has been carried out in the past years to inspect:

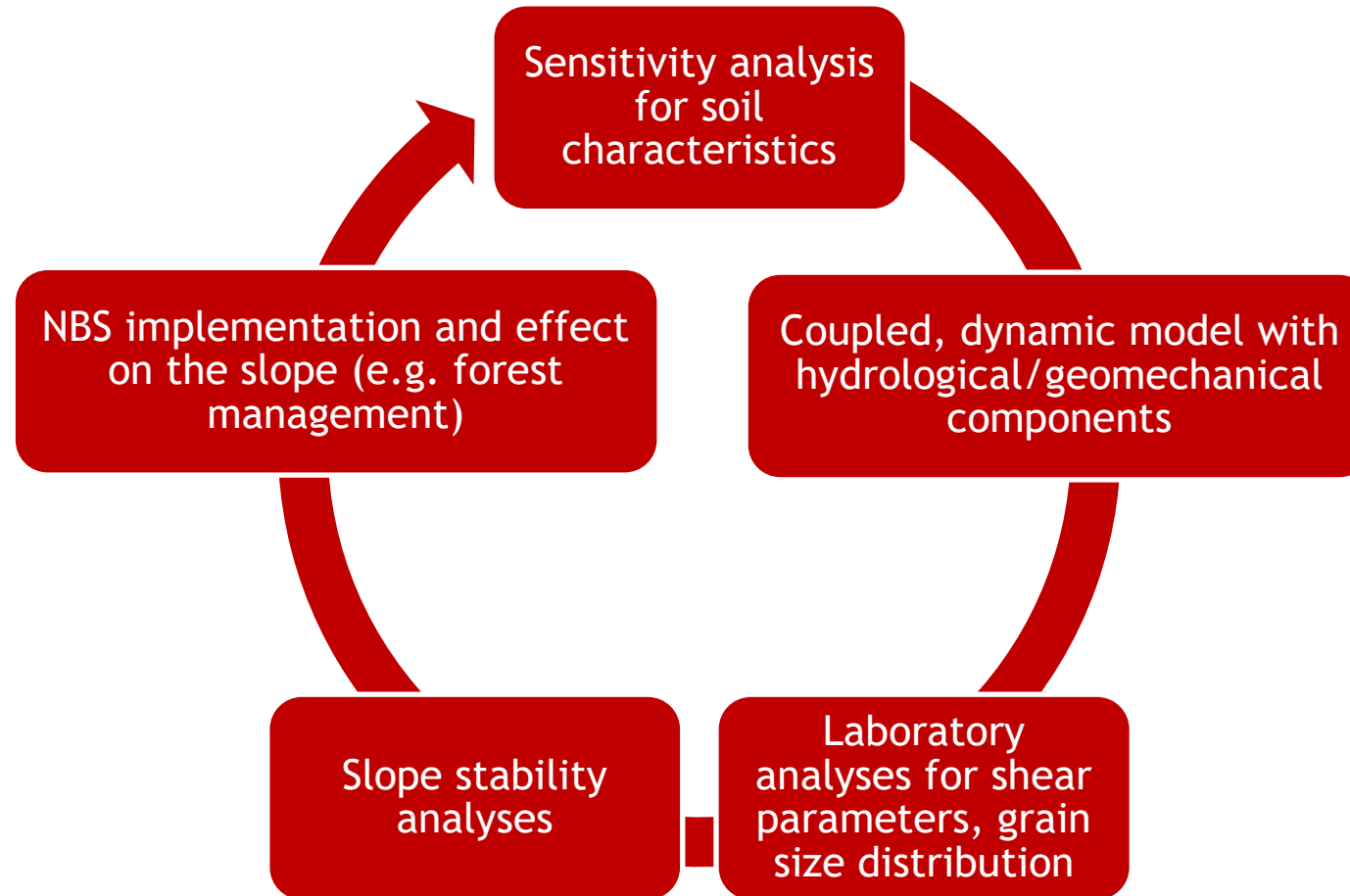
- Groundwater depth changes.
- Slope displacement.
- Snow depth.
- Meteorological data.
- Hydrogeological features.

- ➡ Through a specific sensitivity study the **soil characteristics** have been extrapolated, allowing a series of stability analyses.
- ➡ The **understanding of the triggering movement** and its correlation with **external forcing** (e.g. snow melting, rainfall) are essential elements to design proper NBS (such as optimizing forest management; natural sealing of leaky streams and channels).



# Modelling activity

➔ To this goal, a *multi-impact* modelling approach has been planned:

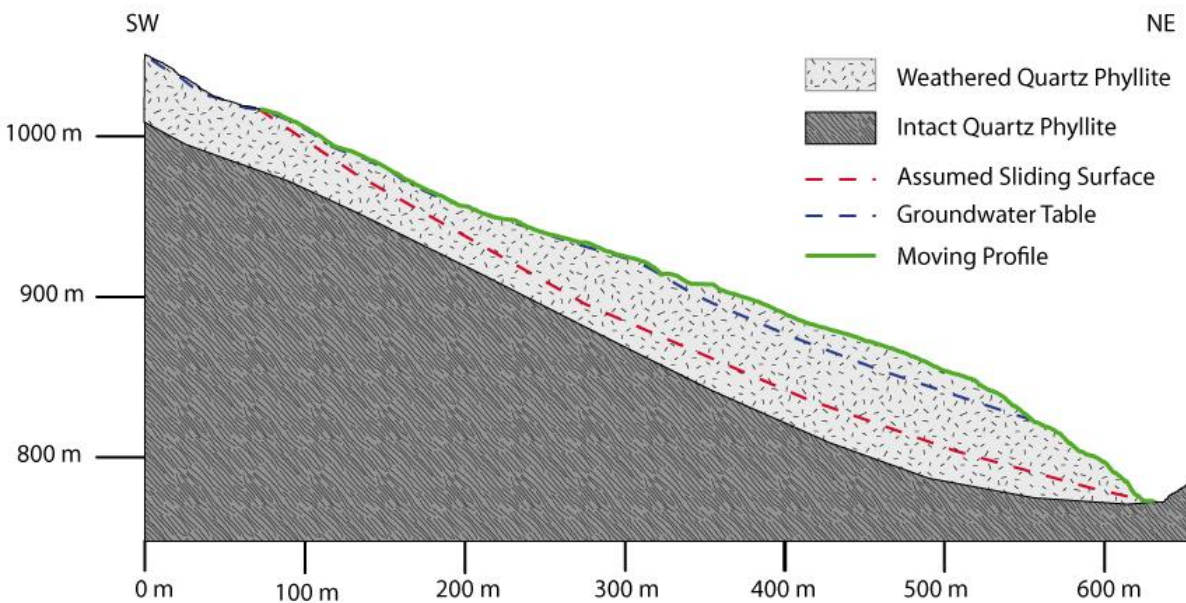




# Current state of the slope stability analysis

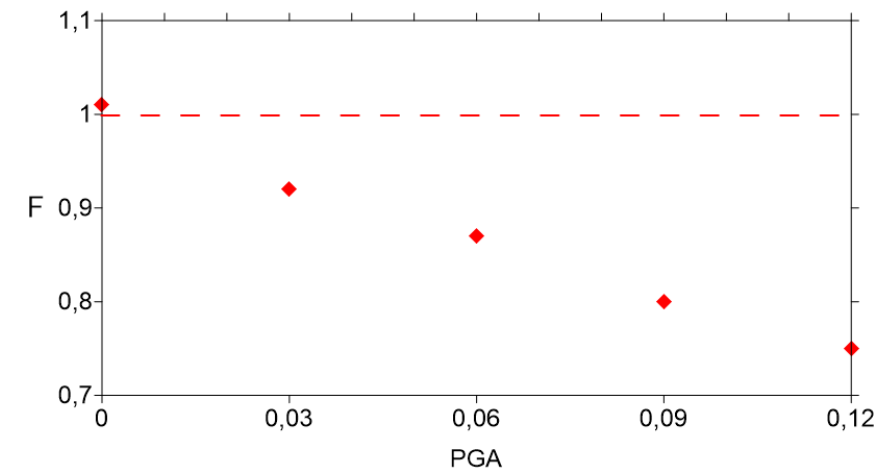
- The active part of the landslide exhibits **slow movement rates in the range of (3,5 – 6) cm/year**. Stability models require, as input, the sliding surface (red line), the moving profile (green line), the groundwater level (blue line). The analysis allows to estimate the **safety factor  $F$**  ( $F > 1$  indicates stability).

➔ The computed safety factor is  **$F=1.03$**  and decreases to  **$F=0.93$**  as the **groundwater level is raised** by one meter. This result matches well with the state of the slope, that moves slowly in response to changes of the groundwater level.



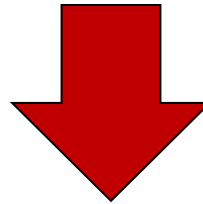
Reconstructed profile of the Vögelsberg slide (Pfeiffer, 2020).

A seismic load has been also included in the stability analysis. The Peak Ground Acceleration (PGA) in the area can reach maximum values of 0,12  $g$ . Results prove that **medium size earthquakes** have the potential to destabilize the slope, strongly reducing the factor of safety.




# Future developments

The current condition of the OAL Austria has been well delineated, which allows us to get a clear understanding of the most appropriate NBS implementation and management for the future.



Forest management includes:

- Optimized tree species and forest stand structure to enhance the **forest's hydrological effects**.
- **Scenario-based modelling** of hillslope hydrology (current state vs. optimized forest management).

 A **dynamical downscaling of climate data** will allow us to estimate the future changes of the external forcing factors. Thus, the analysis presented here will be applied over forthcoming periods of different duration to evaluate the efficiency of the selected NBS.