Monitoring-based identification of nature-based solutions to mitigate the impact of deep-seated gravitational slope deformations

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Outline

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Photos: Zieher and Pfeiffer 2018 and 2019
1) Introduction

Monitoring deep-seated landslides is essential to better understand their complex (forcing) processes. Knowledge about the landslide process is crucial for setting up target-oriented Nature-based Solutions (NbS).

• **Geodetic Monitoring** obtains information about deformation and aims to answer:
  – Where, when and how fast does the landslide move?

• **Hydrological Monitoring** obtains information about (assumed) hydrological drivers:
  – Groundwater conditions (e.g. hydrogeology, flow paths)
  – Groundwater recharge (e.g. hydro-meteorological events)

Nature-based Solutions (NbS): “actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges (…)”. IUCN
2) Study Area

Deep-seated landslide in the Lower Watten Valley (Tyrol, AT)

- Continuously creeping active deep-seated landslide moving between 1.7 – 5.2 cm per year
- Alternating acceleration and deceleration phases
- Infrastructure and houses are damaged

1200 m a.s.l.

900 m a.s.l.
3) Monitoring Framework

- Hydrological Monitoring
- Geodetic Monitoring
3) Monitoring Framework

Geodetic Monitoring

- Automatic tracking total station (ATTS)
- Unmanned aerial vehicle based laser scanning (ULS)
- Terrestrial laser scanning (TLS)
- Airborne laser scanning (ALS)

**Periodic, area-wide**

**Displacement estimation**

**Continuous, single points**

**Point tracking**

Photo: Zieher 2018

Photo: Pfeiffer 2018

Zieher et al. 2019
3) Monitoring Framework

Hydrological Monitoring

Measurements

• Piezometer
• Measurement campaigns at drainages, streams and springs
• Precipitation sampling

Modelling

Numerical model provides spatio-temporal information of water available for groundwater recharge:
• Snow melt
• Rainfall
4) Monitoring and Process Understanding

Consolidation of interdisciplinary monitoring data provides essential information about the landslide process which is required for the identification of nature-based solutions. Following correlations between monitored observables were observed:

- The higher the groundwater level the faster the landslide moves
- Periods with low precipitation input (snow melt and rainfall) correlate with low displacement rates

Basis for planning mitigation measures
4) Monitoring and Process Understanding

Establishing simplified process cascades for the specific deep-seated landslide:

Nature-based Solutions for the shown case study should consider the following mitigation aims:

- **Controls on groundwater recharge**
  - Snow melt
  - Rainfall
  - Evapotranspiration
  - Surface runoff

- Higher *groundwater level*
- Lower *groundwater level*

- Landslide acceleration
- Landslide deceleration

- **Control on groundwater recharge**
  - Lower snow melt input
  - Lower rainfall input
  - Enhance evapotranspiration
  - Drain surface runoff efficiently and minimize infiltration

![Diagram showing nature-based solutions for groundwater management](image-url)
4) Identifying Nature-based Solutions

Following framework of NbS options was developed:

- **Optimize Forest Management**
  - Increase root water uptake
  - Increase transpiration

- **Drainage Trenches**
  - Controlled discharge of surface water
  - Drainage trenches along forest roads

- **Sealing of Streams and Channels**
  - Prevent infiltration of surface water
  - Replace current temporary measures

- **Controlled Snow Accumulation**
  - Implementation of snow fences
  - Controlled discharge of melt water

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Objective of Complementary NBS-Strategy

Reducing the landslide's movement by:
- Reducing the amount of incoming groundwater
- Reducing infiltrating water during snow melt

Zieher, 12 March 2019
5) Conclusion

• Monitoring is essential to acquire knowledge about complex landslide processes

• Process knowledge is essential for identifying target-oriented measures aiming to reduce landslide’s velocity

• We identified four NBS options tackling different parts of the hydrological cycle to support landslide deceleration

→ NBS for deep-seated landslides have to be tailor-made according to the local conditions
5) Outlook

• Further monitoring and modelling tasks will quantify the effectiveness of implemented NbS in future

• Hydrogeological processes will further be investigated to improve and support the detailed planning of further and accompanying measures
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