Mass movements documentation with EO data for assessing the impact on the alpine trails and huts infrastructure

FLORIAN ALBRECHT[1], DANIEL HÖLBLING[1], LORENA ABAD[1], ZAHRA DABIRI[1], GERALD REISCHENBÖCK[2], GABRIELA SCHEIERL[3], TOBIAS HIPP[3], HANNES RESCH[4], GERNOT RESCH[4]

Organisation(en):

[1]Interfakultärer Fachbereich Geoinformatik - Z_GIS, Universität Salzburg, Salzburg, Österreich

[2] MJP Ziviltechniker GmbH, Gmunden, Österreich

[3] Deutscher Alpenverein e.V., München, Deutschland

[4] Österreichischer Touristenklub, Wien, Österreich

florian.albrecht@sbg.ac.at

Abstract

The Alpine infrastructure of trails and huts experiences increased damages due to mass movements like shallow landslides, debris flows and rockfalls. Earth observation data from optical and radar satellites provide new opportunities for mapping and assessing mass movements. We investigate how EO-derived inventory maps and modelled mass movement information can improve the infra-structure management of alpine associations. We first perform a user requirements analysis based on interviews with trail keepers and other stakeholders. Second, we develop mass movement infor-mation using optical and radar satellite data and geospatial modelling techniques for an alpine in-frastructure assessment in four Austrian study areas. Finally, the results are validated in the field and through feedback from practitioners. Preliminary results from the user requirements analysis describe the involved organisations in trail management and maintenance, the roles of the involved people and their particular tasks. It identifies tasks that benefit from Earth observation derived mass movement information.

Introduction

The alpine infrastructure of trails and huts enables access to the Alps and is an essential element of summer tourism. Over the last years, however, al-pine associations registered an increase in damages to the trail network caused by mass movements such as rainfall-induced shallow landslides, debris flows and rockfalls (Figure 1). They can block access to mountain huts and popular hiking routes for weeks or months. Such damages require repair and increased maintenance activity or even re-routing of trails. Consequently, alpine infrastructure man-agement has an increased need for information about mass movements.

Copernicus, the European programme for Earth ob-servation (EO), provides a new opportunity for al-pine infrastructure management. It increased the temporal and spatial resolution of EO satellites with comprehensive coverage of the Earth surface. Thereby, the freely available EO data becomes more suitable for detecting mass movements and per-form an impact assessment on the alpine infrastruc-ture.

In response, the project MontEO (The impact of mass movements on alpine trails and huts assessed by EO data) investigates the opportunities for EO-based mass movement mapping and hazard impact assessment for alpine infrastructure. The key step to commence with the investigation is a user re-quirements analysis. This article presents the method for user requirements analysis in alpine in-frastructure management and describes the in-volved stakeholders, their processes and needs for EO-based information.

Figure 1: Landslide damage on a hiking trail in the Großarl Valley, Salzburg, Austria

Methods

The user requirements analysis for MontEO fol-lowed the structure presented by Albrecht et al. (2016) building on a (1) stakeholder analysis, (2) in-terviews, and (3) an analysis of user needs and re-quirements.

The approach starts with identifying relevant stake-holders that play a role in Alpine infrastructure management. To prepare the discussion with stake-holders, we developed a semi-structured questionnaire based on the MontEO concept.

The MontEO workflow identifies which types of mass movements cause major problems for trail and hut keepers. We then assign the specific EO technology that is capable to derive relevant information about these mass movement types. Our multi-scale approach combines optical and syn-thetic aperture radar (SAR) satellite data (Sentinel-1/2, Pléiades, or similar) for a comprehensive map-ping of mass movements and the detection of mass movement hotspots. We integrate the EO results with ancillary data for mapping landslide suscepti-bility, and for modelling and simulation of rockfalls and debris flows. Finally, we analyse the network of trails and huts in relation to the obtained mass movement information and thereby assess the im-pact of mass movements on alpine infrastructure, i.e. identify the trails and huts that are (potentially)impacted by mass movements. We test the MontEOworkflow in four Austrian study areas in Karwendel,Tyrol, Hochkönig and Großarl/Kleinarl Valley, Salz-burg, and Salzkammergut, Salzburg/Upper Austria.

Figure 2 shows an example map of a mass move-ment event from August 2017 in the Kleinarl Valley that had an impact on hiking trails.

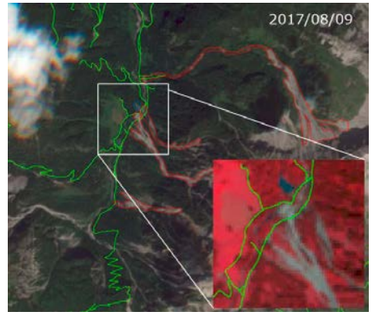

Figure 2: Sentinel-2 image of Kleinarl Valley, Salzburg, Austra, showing debris flows that impacted hiking trails in August 2017. Green lines represent hiking trails, red polygon outlines represent debris flows.

The MontEO concept serves as a basis for discussion with stakeholders. In turn, the discussion with stakeholders aims at collecting user needs, require-ments and quality criteria for verifying the concept's value for practical application.

Our questionnaire contained general questions to the stakeholders about their organisation, their per-sonal role and the tasks for which they are respon-sible. Additional questions asked about the particu-lar tasks that relate to mass movements. Further questions addressed the relevance of mass move-ments in the trail keeper's working area, occurring mass movement types, recent activity, and the way how trail keepers deal with mass movements. We also asked about the stakeholders' expectations to EO-derived mass movement information.

After performing the interviews, we analysed the respective protocols to identify which of the stake-holders' tasks show a need for EO-derived mass movement information and what the requirements to the resulting information are.

Results

Our stakeholder analysis identified several different types of trail keeper organisations: 1) the Alpine as-sociations that are responsible for the accessibility to their huts and that maintain alpine trails out of the interest of the trail users (including both their members and the public), 2) the tourism associa-tions that support tourism activities by taking care of trails below the treeline, and 3) Alpine farmers that own trails for access to their high pastures. In some cases, the afore-mentioned organisati-ons form trail operation associations where the usage of 3 trails is shared. In regions with reservoirs, the elec-tricity providers join such associations because they use the trail in reservoir maintenance. Others or-ganisations with an interest in trails are national parks, nature conservation authorities (i.e. the states of Austria), and landowners that grant a right of way to the trail keepers and users.

We decided to focus the interviews on stakeholders that are ac-tive in high alpine regions where mass movements are particu-larly relevant. Therefore, we addressed Alpine associations. We received feed-back from 17 interview partners which included trail keepers, trail builders and hut keepers from sec-tions of three major Alpine associations in Austria, namely the German Alpine Association (DAV), the Austrian Alpine Association (ÖAV) and the Austrian Tourists' Club (ÖTK). The trail and hut kee-pers were mostly from the sections that are active in our study areas. We also interviewed officials in the trail man-agement of the main associations.

The roles that people fulfil in trail management and mainte-nance include:

- In the main organisation of Alpine associations
  - Trail management officials

- In sections of Alpine associations with a dedi-cated working area
  - Head of trail keepers
  - Trail keepers
  - Volunteers (from the members of Alpine associations, helping in trail construction)

- From other organisations
  - Members of mountain rescue services
  - Trail builders (professionals from compa-nies or tourism associations)

For large sections of an Alpine association, the trail keeper duty may be split among several trail keep-ers that have one head. Smaller sections may have a single trail keeper or even assign the trail keeper duty to the hut keeper.

The are several main tasks in trail management and mainte-nance that have a set of subtasks each:

- Strategic trail management
  - Instructing trail keepers and capacity build-ing
  - Support services (e.g. for organizing and acquiring funding for trail maintenance and trail status docu-mentation)
  - Strategic planning of expected trail mainte-nance effort

- Operative
  - Documentation of trail maintenance status
  - Planning of large trail revisions, new con-structions and the re-location of trails to new routes (e.g. for replacing unmaintain-able trails)
  - Apply for funding
  - Contracting trail builders or organizing re-vision campaigns with volunteers

- Trail maintenance
  - Performing trail inspections
  - Doing trail servicing and small repairs
  - Marking trails and setting up signposts

- Trail construction
  - Implementing revision campaigns for trails
  - Construction of bridges, railings, ladders, stairs, installing safety ropes
  - Building trails in new areas

While the strategic trail management mostly hap-pens in the main organisation of Alpine associa-tions, the operative ma-nagement is done in their sections. The trail keepers, and in some regions pro-fessional trial builders, perform the trail mainte-nance. Trail constructions are organized by trail keepers and happen with the work of volunteers, with professional trail builders, or with members of the mountain rescue services for high alpine trails.

The interview partners reported the following causes for trail damage:

- Mass movements
  - Debris flows and landslides that cover trails or destroy bridges
  - Rockfalls that can damage safety ropes and railings
  - Deep-seated landslides that are a risk for the opera-tional infrastructure in the vicin-ity of huts

- Snow pressure
  - Heavy winter snow loads damage sign-posts, bridges, etc.

- Avalanches
  - Avalanches can take safety ropes with them

- Storm and windfall
  - Fallen single trees and windfalls can block trails

- Erosion
  - Rain can wash down loose material from trails

- Wearing of trails
  - The erosion of trails can be increased through use by hikers and mountain bikers (particularly when they are electric)

The causes of trail damage differ depending on the region. Mass movements play a major role in work-ing areas of Alpine as-sociations that are active in high alpine regions and in regions where the geolog-ical situation favours them. The interview partners considered EO-derived mass movements infor-mation in the form of inventory maps, hotspot maps, and hazard im-pact maps especially useful for strategic planning of expected trail maintenance ef-forts and for the planning of trail revisions, new con-structions or re-routing of trails. The identified tasks have an impact on many of the other tasks in trail management and maintenance. There was also a case mentioned where EO-derived information about deep-seated landslides can be use-ful to bet-ter understand the impact on the operational infra-structure in the vicinity of a hut.

Discussion and conclusion

The interviews with trail keepers allowed us to iden-tify relevant stakeholder orga-nisations, the roles and tasks of people involved in trail management and main-tenance, the causes of damage to trail net-works, and the tasks where trail kee-pers expect a benefit from EO-derived mass movement infor-mation. This in-vestigation enables us to analyse and de-fine requirements and associated quality criteria for the mass movement informa-tion that shall sup-port the stakeholder workflows in the next step.

Currently, we are developing methods for mass movement mapping using optical and radar satellite data and geospatial modelling techniques for an al-pine in-frastructure assessment in four Austrian study areas. The requirements and qua-lity criteria will be a basis for the valida-tion of the results in the field and through feedback from practitioners. We expect that a thorough analysis of the outcomes of MontEO will contribute to improved maintenance efficiency for the benefit of a safer alpine infrastruc-ture with an in-creased value for the tourism indus-try.

Literature

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