Study on the potential of Nature Based Solutions for the protection of a rockfall site at Artouste (French Pyrenees)

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Abstract:

The H2020 PHUSICOS project aims at providing new insights into the effectiveness of Nature-based solutions (NBSs) against natural hazards in the context of climate change. One of the demonstration sites is the mountain region of Pyrenees located in the municipality of Laruns (French). The site consists of a very steep slope prone to rockfalls (on average higher than 40°), which overlooks the D934 road that gives access to the Portalet pass in Spain. The average daily traffic ranges between 1500 - 2500 vehicles/day to more than 3000 vehicles/day during summer and winter weekends. The road is highly exposed to rockfall that has caused a fatality and large damages over the last years.

Here, we aimed to quantify the benefits of NBSs (forest & protection systems) on the mitigation of rockfall hazard at road level. The rockfall hazard assessment was based on field expertise as well as on the use of high-resolution airborne LIDAR, Terrestrial Laser Scanners (TLS), botanical surveys and 3D numerical-based simulations of boulder propagation. This rockfall hazard assessment was achieved according to the following steps: 1) mapping of the rockfall departure zones, 2) inventory of boulders/events and the definition of scenarios with different classes of boulder volumes (e.g., 0.25 m^3 and 1.00 m^3) and associated return periods (e.g., 10 and 100 years, respectively), 3) simulations of boulders trajectories using the Rockyfor3D software (Dorren et al., 2006), where the implementation of different NBSs as well as the protective effect of the forest were carried out.

Particular attention was paid to correctly map source areas and estimate input settings for simulations of boulders trajectories. Thus, source areas were defined by applying the method proposed by Loye et al. (2009) on morphometric analysis of DTMs, which allows defining different slope thresholds corresponding to an increasing probability for a pixel to belong to a cliff. A clustering approach was then designed to map continuous release areas: cliff neighbouring pixels with slope steeper than these intermediate thresholds were also included in sources areas. Moreover, the soil roughness (here, the probability of a boulder to meet an obstacle of a certain height along the path) was estimated based on the differences between DTMs of different cell sizes and degree of smoothing. The modelled roughness was then validated based on field data from some sample areas. The soil type mapping, as needed to carry out simulations of boulder trajectories, was carried out by combining different sources of information: 1) the geological map of the area, 2) the clustering of

homogeneous slope zones, 3) the clustering in zones of homogeneous roughness, 4) the detailed inspection of the 3D shaded view of the DTM, 5) the detailed inspection of the high resolution orthophotography of the study site. Again, the modelled soil types were validated based on field data from some sample areas.

Rockfall simulations were then validated with botanical-based evidence in two selected plots (Moya et al., 2010). In particular, we focused on the analyses of scars on trees as they represent the potential height of boulder transport and can be dated dendrochronologically to identify temporal rockfall patterns. Moreover, a detailed forest inventory was performed in the studied site using mobile terrestrial laser scanning (MTLS) in order to detect the position of each tree as well as information such the tree species, the tree diameter at breast height (DBH) and the height of each tree. To extend the information obtained from the detailed surveys over the entire survey area, we performed and calibrated a semi-automated forest model based on a canopy height model (CHM) developed by comparing the DSM and the DTM using the Ecorisq FINT software (Dorren, 2017; Dorren et al., 2006).

The considered NBSs consist of wooden rockfall barriers of 2.25 m height with absorption energy of 100 kJ. Based on the modelling outputs, no relevant improvements of rockfall hazard are noted with NBS (except locally). However, a shift of the highest values of kinetic energy and rebound height is obtained. Thus, the designed NBSs are not sufficient to significantly reduce the risk of rockfalls, but such NBSs might be considered as an additional solution for dampening the rockfall intensity limiting the sizing and, thus, the economic and environmental impacts of other interventions such as steel rockfall barriers.

Acknowledgements:

This work has been conducted within H2020 PHUSICOS project (Grant Agreement No. 776681).

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