METHODS FOR ROCKFALL RISK ASSESSMENT AND ESTIMATION OF RUNOUT ZONES: A CASE STUDY IN GOTHENBURG, SW SWEDEN

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BACKGROUND

Rockfalls occur around Sweden every year, and the country lacks a national risk evaluation and detailed documentation related to this natural hazard. A first step to address this problem is to map the areas under possible threat of rockfalls, by considering two fundamental aspects: i) identification of the areas where blocks may lose support and start moving downslope (source areas). ii) estimation of the extent of the blocks' trajectory until they finally stop (runout zones).

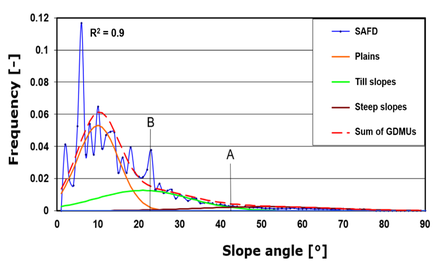
Potential rockfall source areas can be outlined using statistical calculations; whereas runout zones can be simulated using modelling software. CONEFALL and RockyFor3D are computer programs that offer the possibility to estimate the vertical and horizontal extent of the runout zones for a specific rockfall source

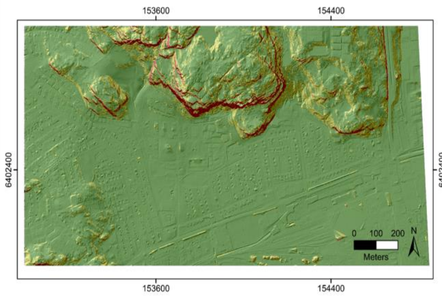
FJÄLLBO, GOTHENBURG (SW SWEDEN)

Why Fjällbo as verification point?

- Popular climbing area where cliffs reach more than 90 meters in height.
- Large talus slopes evidence both historic and recent rockfalls. The most recent rockfall occurred in 2017 after a pillar of approximately 150 Ton detached from the rock wall.
- Nearby hiking trail constantly transited and a growing residential area situated at 50 m from the base of the cliffs.

SLOPE ANGLE DISTRIBUTION (SAD)





The SAD provides a systematic methodology to detect potential rockfall sources by performing geomorphometric analysis in combination with the geological data. The morphological units in the Fjällbo area were classified as plains, till slopes and steep slopes.

Figure 1. Top: SAD analysis performed in Fjällbo area. A indicates the slope angle threshold above which all angles are considered potential rockfall sources (40°- 42°), and B is the mode of the steep slopes. Bottom: Reclassification of the slope angle values according to the SAD analysis results and its relationship with the topography.

CONEFALL

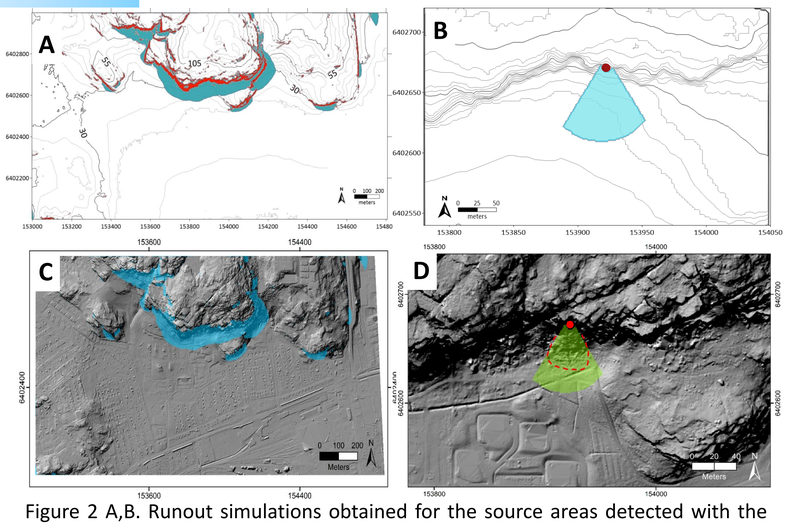


Figure 2 A,B. Runout simulations obtained for the source areas detected with the SAD for the Fjällbo area and for the 2017 source, respectively. C,D. Runout zones and their relationship with the topography and morphology of the area. In red: Measured extent of 2017 runout zone.

The results are highly dependent on the topography and morphology of the terrain and constraining the aperture angle is highly recommended in order to adjust the lateral extent of the runout zones to the local slope conditions.

ROCKYFOR3D

The sensitivity and influence of individual parameters was tested for the Fjällbo area. Block shape influences the lateral extent of runout zones, as rectangular blocks can hit the ground in several different ways. Block mass controls the depth of penetration and, therefore, the energy dissipation and deacceleration of the blocks. The coefficient of restitution has two components, the normal, which is associated with the Mean Obstacle Height (MOH), and the tangential, related to soil type in the slope. This parameter governs the bouncing properties of the blocks and most of the extent of the runout zones. And finally, the efficacy of forested slopes as protective agents is mostly controlled by the density of the forest, rather than the Diameter at Breast Height (DBH).

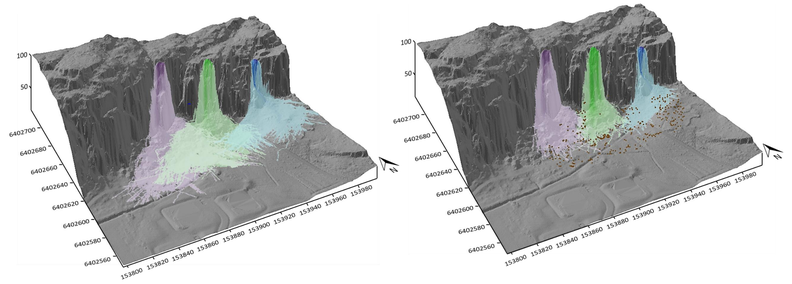


Figure 3. Left: Simulation of three different rockfalls in Fjällbo with a conservative approach. Right: Simulation with realistic parameters.

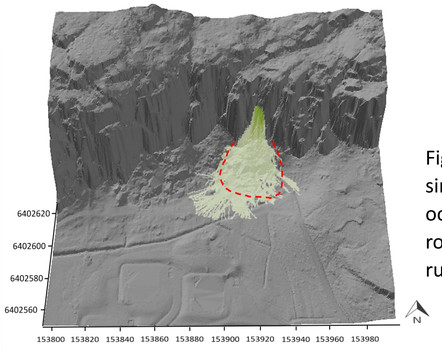


Figure 4 shows the simulation using similar conditions and parameters as occurred in 2017. Location of 2017 rockfall source (red dot) and measured runout zone (red dashed line).