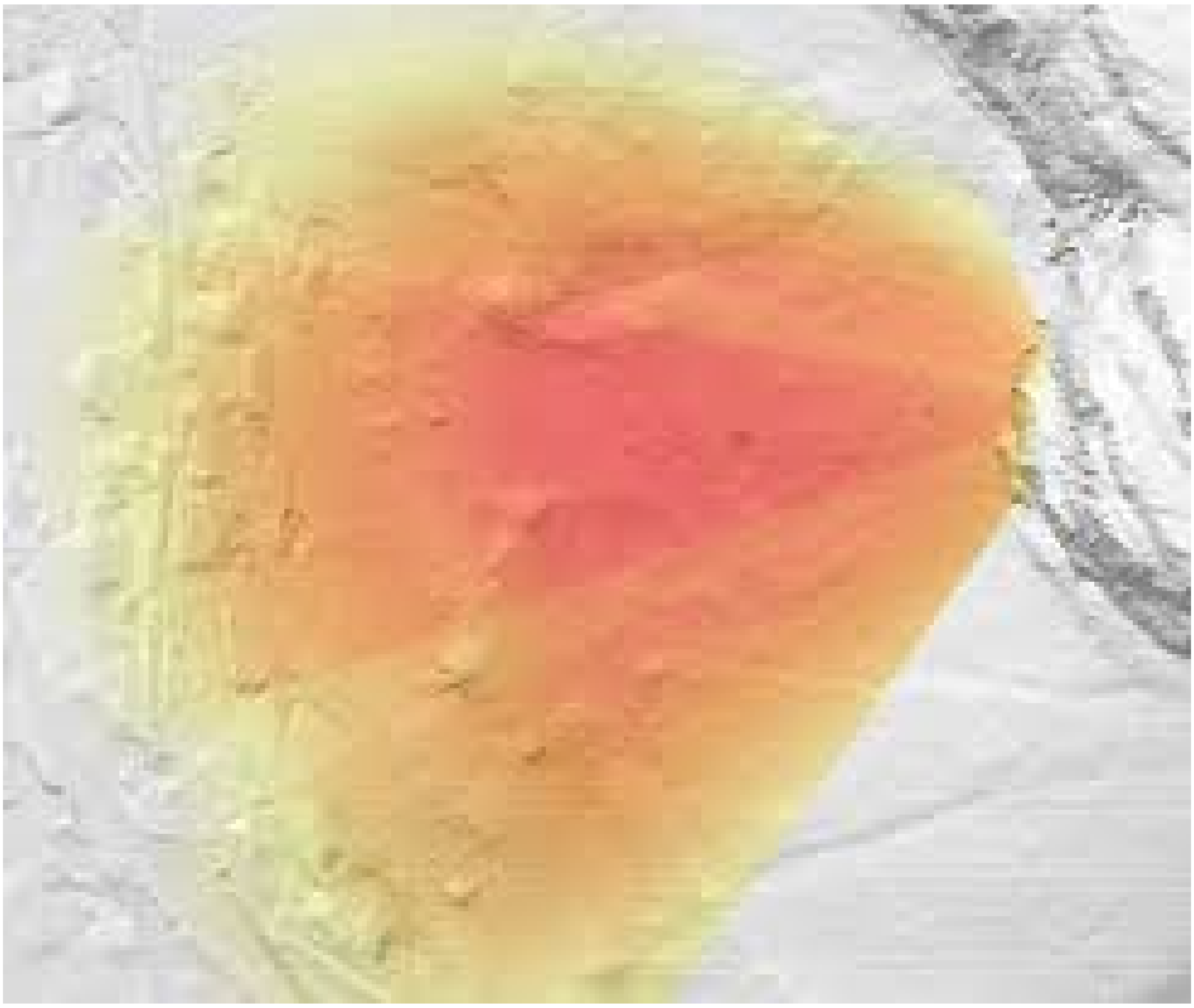
ELine - Energy Line Calculation

Manual



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1 Introduction

1.1 Context

Rockfall processes are gravitational mass movements that can cause major damage due to their high kinetic energies and therefore represent a gravitational natural hazard. To assess the hazards and risks of rockfall processes, the ranges and energies must be calculated with spatial resolution Hantz et al. (2021). Due to the complex mechanics and the large number of influencing factors, the calculation of rockfall processes is associated with various challenges Melzner & Preh (2012).

In principle, even complicated rockfall processes can be calculated with computer-aided models, but even in simple cases there are challenges in the parameterization of the models. To estimate the required parameters, a lot of data is needed, which is often not available or subject to large uncertainties. For a preliminary assessment of rockfall processes at the level of hazard indications, approaches with complex models are often not expedient.

1.2 Objectives

The software ELine, which is based on an energy line approach, is a tool for the preliminary assessment of fall processes. The simple physical principle is applied to a digital terrain model using a geometric approach to estimate the ranges and energies. In addition to the raster map of the digital terrain model, only a few parameters are required to run the simulation, which can be estimated with quite an accepable degree of certainty.

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2 Methods

2.1 Mechanics

The basic physical model for the calculations in ELine is the law of conservation of energy combined with a linear approach for energy dissipation (Figure 1). This approach is based on the geometric principle of the propagation ratio interpreted as the energy line angle Heim (1932). The propagation ratio can also be understood as a friction angle for the movement of a mass on an inclined plane Jaboyedoff & Labiouse (2011). It should be noted that the propagation ratio depends on various factors such as the block size, the ground surface and the terrain shape Evans & Hunger (1993). For a more realistic representation of propagation cones, the propagation is geometrically limited with a cone opening angle Loye et al. (2008). This makes it possible to calculate for each grid cell whether it can be reached by a starting cell and, if so, with what kinetic energy.

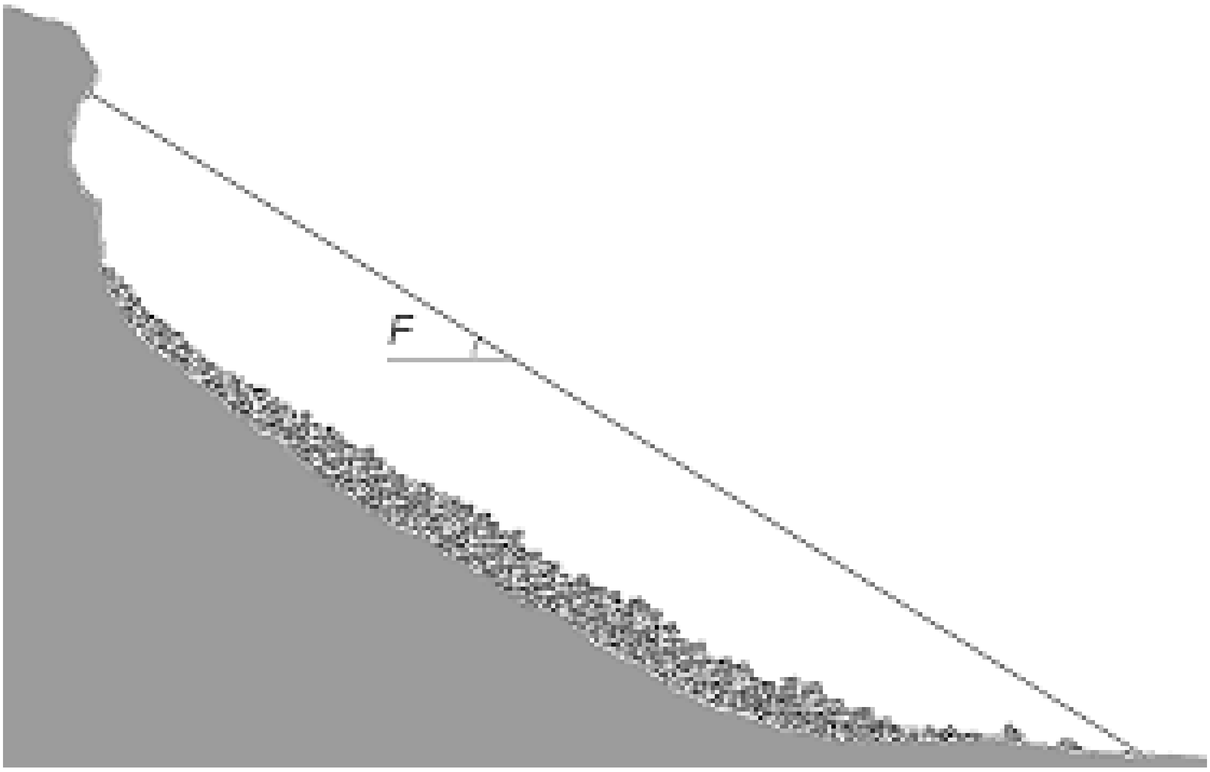

Figure 1: Illustration of the energy line principle applied in the ELine model

For each pair of available grid cells and specified start cells, their spatial distances are determined in the cartesian coordinates x, y and z. For a grid cell to be reached, the ratio of the vertical distance to the horizontal distance must be greater than the tangent of the energy line angle ϕ (equation 3). Furthermore, the deviation in the horizontal plane from the exposure angle ϵ of the starting cell must be smaller than the cone opening angle κ (equation 2).

$$\phi < atan(\frac{\Delta z}{\sqrt{\Delta x^2 + \Delta y^2}}) \tag{1}$$

$$\kappa > atan2(\frac{\Delta y * cos(\epsilon) - \Delta x * sin(\epsilon)}{\Delta x * cos(\epsilon) + \Delta y * sin(\epsilon)}) \tag{2}$$

If both conditions are met for a grid cell, it is counted as reached and the kinetic energy E is calculated (equation 3). In addition to the spatial distances and the energy line angle, this is also dependent on the gravitational acceleration g, the block density ρ and the block volume V.

$$E = g * \rho * V * (\Delta z - tan(\phi) * \sqrt{\Delta x^2 + \Delta y^2}) \tag{3}$$

The energy line angle essentially determines the calculated ranges and energies and is the central parameter of the model. Together with the gravitational acceleration, the block density and the block volume, it forms a set of physical parameters, while the cone opening angle is a purely geometric parameter with no physical equivalent.

2.2 Program

The ELine model is based on the C programming language and is executed locally on Windows operating systems. Additional programs are not required for execution. A GIS program is very useful for preparing the input files and for post-processing the output files.

According to the defined start cells and the simulation parameters, it is calculated for each grid cell in the perimeter whether it can be reached by the rockfall mass. Furthermore, the kinetic energy of the rockfall mass and the passage frequency are calculated according to the specified start cells. The calculations are deterministic and the model always generates the same output data with the same input data.

3 Application

3.1 Installation

To install ELine, a user account must be created on ecorisQ. The program files from ELine can be downloaded from this platform. The program is installed by executing the file $ELine\_install.exe$. Furthermore, the license must be installed by executing the file $licenseWin.exe$.

3.2 Input data

Two input files can be included in the ELine program (table 1). A digital elevation model (dem) is required as a mandatory input file. This contains the terrain height as a raster for the corresponding perimeter. The path is specified in the $InputDEMfile$ field. For user-defined start cells, an input file with start cells (start) can also be included. The path to the file is specified in the $fromfile$ field. The extent and resolution of the two raster files must match.

Name	Format	Content
dem	.asc	Raster file with a digital elevation model over the perimeter of the study
start	.asc	Raster file with user-defined start cells over the perimeter with value 1 for start cells and value 0 for all other cells

Table 1: Description of the ELine input files

Three different options are available for defining the start cells (table 2). The two options without an additional input file with start cells are each based on a limit value for the angle of inclination α, so that only steep grid cells are counted as start cells. The option with the dependence of the limit value for the slope angle on the cell size L of the raster files used assumes 55 ° at 1 m and takes into account smoothing effects depending on the resolution (equation 4).

Option	**Description**
From slope threshold based on cell size	All cells with a slope α greater than the limit value dependent on the cell size L are used as start cells.
From custom slope threshold	All cells with a slope α greater than the user-defined limit value are used as start cells.
From file	The start cells are user-defined in a raster file in .asc format.

Table 2: Options for defining the start cells

$$\alpha = \frac{55 * \pi * L^{-0.075}}{180} \tag{4}$$

Four input parameters must also be defined (table 3). The values must be entered as whole numbers in the specified unit or selected from the specified values. With the simple calculation approach, only the energy line angle and the cone opening angle have an influence on the ranges. The block volume and block density are only required to calculate the energies.

Name	**Unit**	**Description**
Energy Line Angle	°	Angle of the general slope in the lateral slope profile. Empirical values for rock and boulder impact are between 28 and 32 °, on wooded slopes between 30 and 36 °.
Cone Width	°	Angle of maximum deviation from the central fall line in the horizontal plane. Guide values are between 10 and 30 ° depending on the topography, the shape of the block and the vegetation.
Moving mass volume	m^3	Volume of the camber mass in relation to a single block. The model RockFreq can also be used to estimate the block volume.
Moving mass density	$kg*m^{-3}$	Density of the camber mass in relation to a single block. The table from RockforNET can be used to estimate the block density.

Table 3: Input parameters for the simulation in ELine

The input parameters should be based on data from historical events from the perimeter if available and otherwise on reference values from the literature. The results of the simulation should be checked for plausibility and the input parameters adjusted if necessary.

3.3 Executing ELine

Before execution, a path for the output data must be specified in the *Outputdirectory* field. The simulation can then be started using the *Run* button. During execution, the progress is displayed in a bar. Information about the execution is displayed in a control window. The user interface has a single-layer structure and is shown in full below (Figure 2).

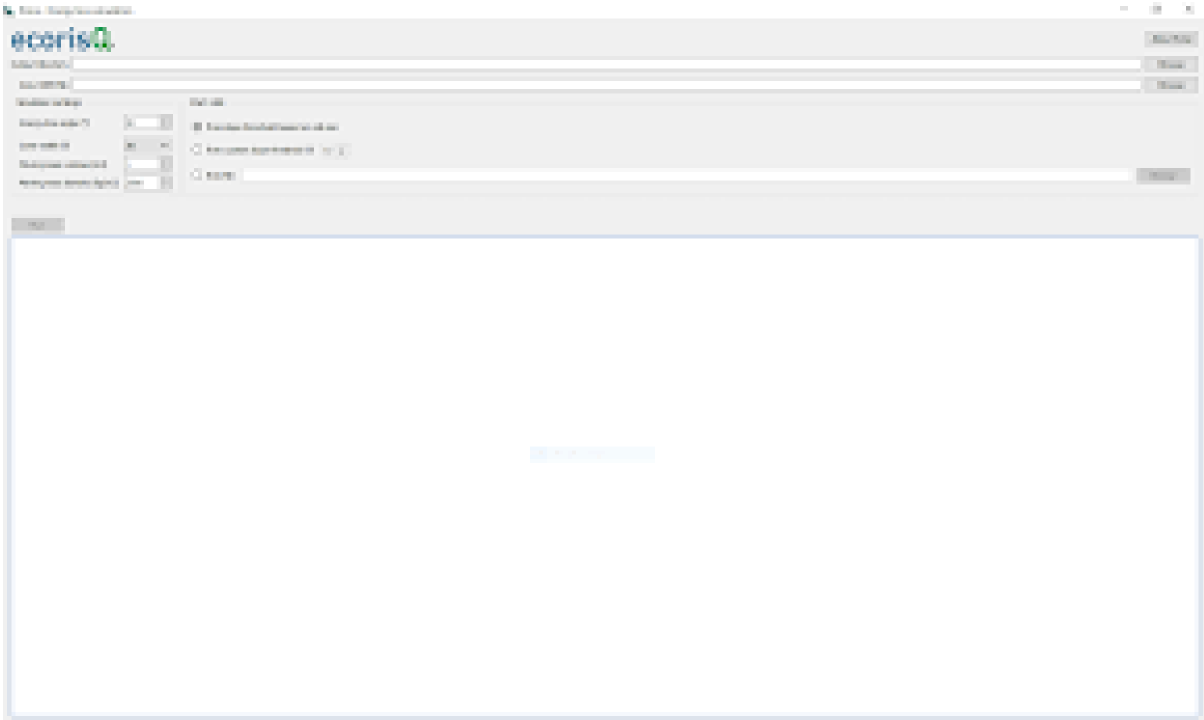

Figure 2: Illustration of the ELine program user interface

Possible errors during execution are displayed in the user interface and are often due to incorrect input files or paths. The input files must be in the specified format and match spatially and the paths must exist and have the necessary permissions.

3.4 Output data

The output data of the ELine model comprises three files (table 4). The calculated values for the passage frequency and the kinetic energy are output in raster files for all cells in the perimeter. There is also a text file with information on the simulation.

Name	Format	Content
EL_E_grid	.asc	Raster file with the maximum kinetic energy for all cells in the propagation cone.
EL_Freq_grid	.asc	Raster file with the summed passage frequency for all cells in the propagation cone.
ELine_log	.txt	Text file with information on input data and output data of the simulation.

Table 4: Description of the ELine output files

In any case, the calculated ranges and energies should be checked for plausibility. If necessary, the input parameters should be adjusted, whereby the energy line angle in particular should be used as an adjusting screw. Depending on the use of the output files, it may be useful to normalize the passage frequency with the number of start cells and the kinetic energy with the volume, mass or weight of the block, whereby these values can all be found in the output text file.

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Versioning

Version	Date	Model	Language
1	2019	v1.1	German
2	2025	v1.4	English