

Protection of areas against avalanches, mudslides and rockfalls - Supply, Flow, Demand

General description:

The following model is an approach to delineate areas where the biotic ecosystems (forests) contribute to the mitigation of natural hazards and the protection of human assets from hazardous natural processes. At the Alpine-wide scale, this has been done by combining separate regional models for avalanches, rock-falls and water channel relevant processes. These models were created building on methods developed by the ProAlp Project (Bauerhansel et al. 2009) and Voigt (2010). The models use topographical information derived from the 25m EU DEM and statistically derived threshold values identified by earlier projects and assessments (performed in all Alpine countries) to model potential avalanche and rock-fall release and transition zones. **The flowchart below** describes in detail the calculation procedure to derive the developed indicators per local administrative units (LAU2) of the Alpine Space.

Input data

- DEM (slope, slope-length, flow direction, watershed, plan curvature, contour lines)
- Land Cover
- River Network

Calculation processes

Avalanche release and Transition zones

(1) Calculate potential avalanche release areas: Select all areas with a slope between 28° and 55°, a plan curvature between -2 and 0.2, a forest land-cover and if there is no better information on potential snow-accumulation available above an altitude threshold (Bauerhansel et al 2009).

(2) Split larger areas: To get more realistic snowfields the result of the previous calculation has to be split into smaller areas. To take flow processes of avalanches into consideration this should be done by using very small watersheds that indicate the same flow direction of an area. The areas can be split into horizontal sections using contour lines (50m) to create "snowfields" with a vertical extent no larger than 120m.

(3) Calculate avalanche cost path: The cost path represents the easiest way down a slope following the highest elevation differences from one raster pixel to the next. In Arc GIS this can be accomplished with the tool (cost path) using the Flow-Direction as Cost Backlink raster and the DEM as Cost Distance Raster.

(4) Calculate energy line angle for every release area: The energy line,

inherit/inherit;;windowtext;;inherit>orgeneralizedgradient, represents the angle of the connecting line from the release point and the outer edge of the run out zone of a mass movement with the horizontal plan. (Bauerhansel et al 2009)

In Arc GIS the calculation of the Energy Line Angle can be done with the following steps:

- Creating an integer raster with the elevation of the release areas.
- Running the tool Euclidean Allocation and Distance with the integer raster as Input (to speed up the calculation, a maximum distance of 2000m should be set).
- Using the Raster Calculator, subtract the result from the DEM. The value you get is the elevation difference from every pixel to the release zones Δh .* The Euclidean Distance calculated in step (b) represents Δl .
- The energy line angle can then simply be calculated with $ELA = \text{atan}(\Delta h / \Delta l)$ (→Arc GIS calculates angles in radians to get a result in degrees you have to multiply it with 57.2958)

(5) Limit avalanche Paths with energy line angle:<font

inherit/inherit;;windowtext;;inherit>Knowing the avalanche path, the energy line angle allows a rough estimation of maximal runout distance. The previously measured events occurred at an ELA of 17° - 47° with the mean 28°. Events with ELA 17° are very improbable. We used this threshold for our approach to consider all possible events. (Bauerhansel et al. 2009, PARAMount Project 2012).

Rock-fall Release and Transition Zones

(6) Calculate potential rock-fall start zones:Similar to the avalanche release areas, this can roughly be done by selecting all areas with bare-rock land-cover and a slope steeper than 43°. In the Alpine-wide approach we had to use CORINE Land Cover as the input dataset where most rock surfaces are not delineated (because of resolution and minimum mapping width). For that reason, we also included all the areas without vegetation. Depending on the DEM resolution, different slope thresholds should be applied (Berger et al 2010).

DTM resolution/cell size [m]	Threshold slope gradient [°]
1	55
5	49
10	46
25	43

(7) Create Cost Raster:A cost raster represents the theoretical costs a falling rock would have to overcome from one area to the next (pixel to pixel). These costs depend on the slope length and the land-cover/surface roughness. The highest costs are found in flat, forested areas and low costs exist in steep areas without forest-cover. A single raster can be created by combining two reclassified slope rasters (one for forest areas and one for all other surfaces). The reclassification should occur with the following values:

Slope	Costs no forest	Costs in forest
<5°	10	30
>5-10°	9	27
>10-15°	8	24
>15-20°	7	21
>20-25°	6	18
>25-30°	5	15
>30-35°	4	12
>35-40°	3	9
>40-45°	2	6
>45°	1	3

(8) Calculate energy line angle for every start zone: Energy line angle is calculated using the same methodology as in step 4.

(9) Perform Path Distance analysis to calculate maximum runout lengths of falling-rocks:

The threshold of 2250 was used which is approximately a runout of 250 meters in forested terrain (assuming the same dbh and tree density in all forests). With better information on the tree stands in forests different thresholds could be applied using the Rockfor^{NET} tool, found here:

<http://www.ecorisq.org/rockfor-net-en>.

Areas relevant for water channels

(10) Delineate Forest areas with a protective effect for water-channels: All areas with an on-surface distance to water channels of between 10m (trees too near to the channel can have negative influence) and 200m and a slope steeper than >20° are potential erosion and mudslide risk zones that could clog up the river. Forests within this zone are thus particularly important in preventing erosion and events.

Supply Indicator creation

(11) Combine areas where forests have a protective function: By merging all natural hazard zones that already have a forest land-cover, the sites of protection forests are identified. By definition, the protective function of forests exists in all avalanche release and transition zones, rock-fall transition zones and water channel relevant terrain.

Demand indicator creation

(12) Calculate natural hazard potential: Merge the spatial extent of the avalanche and rock-fall transition zones calculated above.

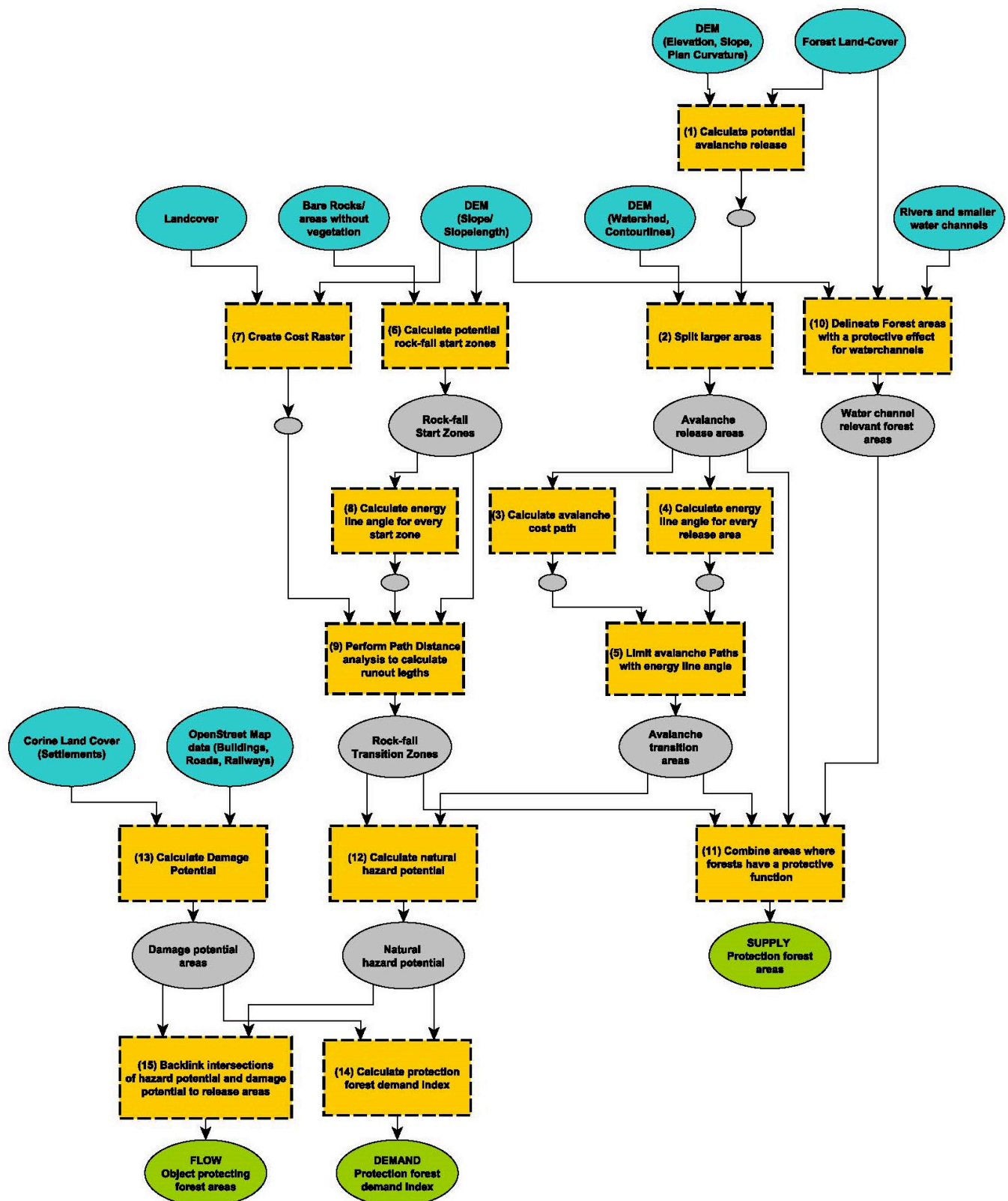
(13) Calculate Damage Potential: Create a raster with all human infrastructure, such as settlements areas, built up areas, buildings, roads and railways.

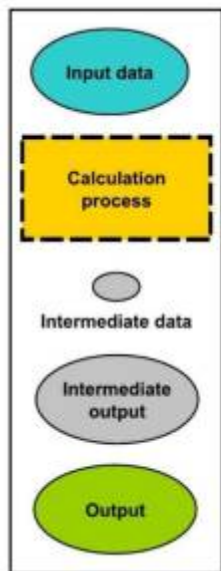
(14) Calculate protection forest demand index: Overlay the natural hazard potential and the damage potential areas. This allows one to identify all of the Infrastructure in potential hazard zones that is in need of protection.

Flow indicator creation

(15) Backlink intersections of hazard potential and damage potential to release areas: In the case of avalanches all the transition zones that intersect with infrastructure have to be traced

back to the corresponding release area. Using Raster in ArcGIS, this can be done by inverting the DEM and performing a new cost path analysis starting from the intersected damage potential areas. Finally, by combining the avalanche release and transition zones as well as rockfall transition zones that possibly harm infrastructure we are able to identify Object-protecting forest.





Input data→elements that hold a value or a reference to data stored on disk. It is usually a spatial explicit information coming from official sources.

Calculation process→ the actual operation performed on the data. The number preceding the item refers to the number in the model description.

Intermediate data→ for each calculation process intermediate data is generated. This data, however, is usually not significant itself, but is used as an input for the next calculation step.

Intermediate output→ is intermediate data that has a significance for the ES evaluation.

Output→ is the result of the calculation process. It is typically one of the ES indicators, either Supply, Demand or Flow.

Flowchart depicting the procedures used to derive the supply, flow and demand indicators

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