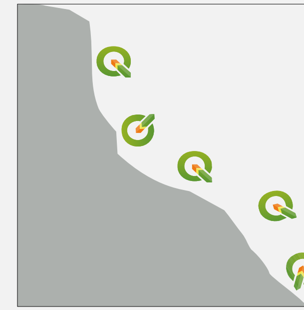

QPROTO – a QGIS plugin for rockfall analyses at small scale

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July 2019

Small scale hazard analysis

A rockfall hazard analysis can be carried out at a small scale (with reference to a valley, a municipality, etc.) for **land planning purposes.**

In this case:

- ✔ detailed data relating to the **characterization of the slope are often not available**;
- ✔ **simplified computation methods** are needed, based on equivalent global parameters.

Small scale hazard analysis

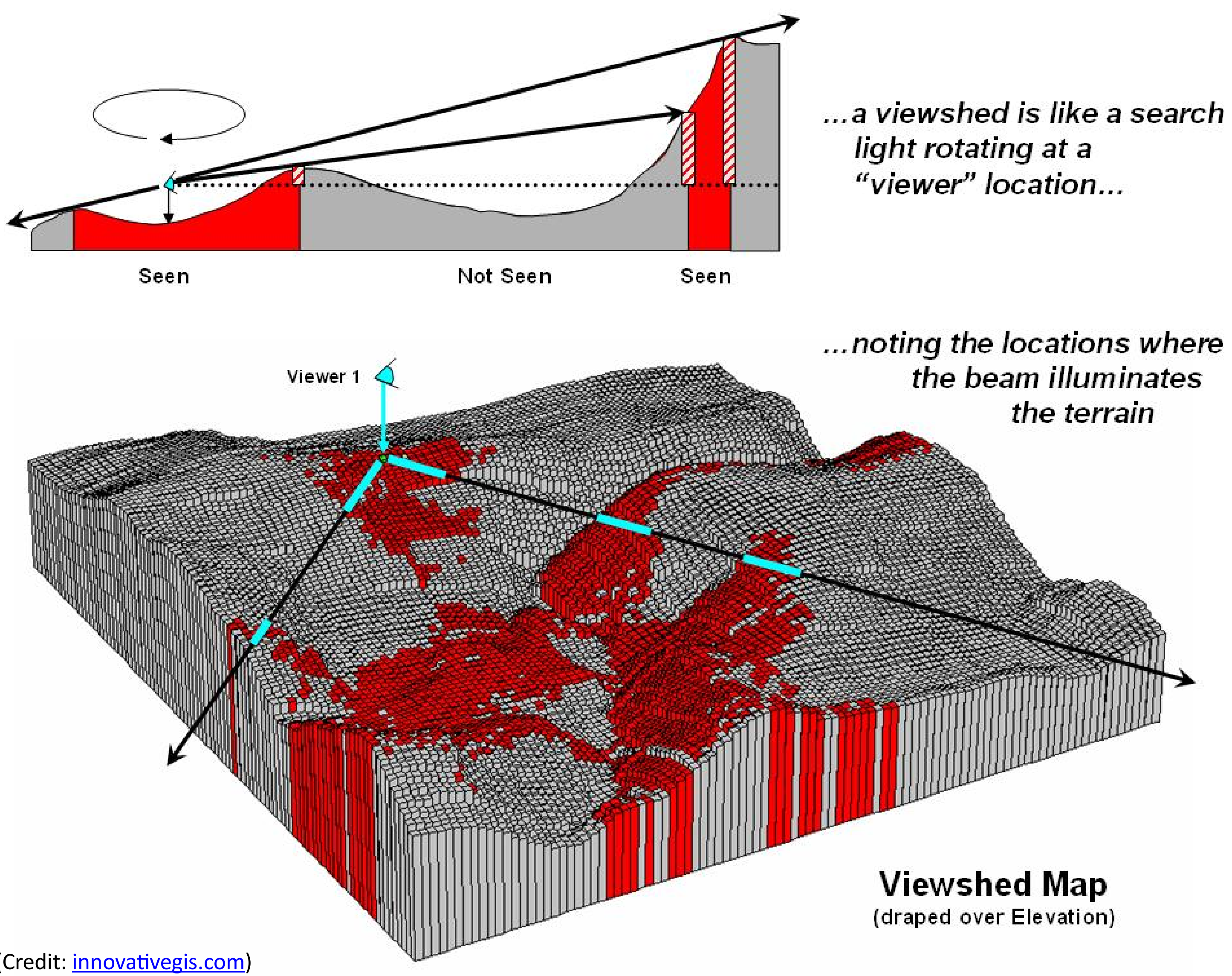
A procedure developed by **Polytechnic of Turin** and **Arpa Piemonte** is illustrated below, based on **the *Cone Method*** *(Jaboyedoff & Labiouse, 2011)*.

- The potential of the cone method lies in its easy implementation in a GIS software, thanks to the **visibility functions** (*viewshed* function);
- In this way it is possible to **identify the areas** of a surface (the cells of a DTM) **which are seen from one or more points of the surface** itself;
- The proposed procedure, carried out in QGIS environment as a plugin tool, aims to **preliminarily evaluate**, on a small scale, the effects of a **rockfall** phenomenon along a slope **in terms of runout area, velocity and energy**.

Jaboyedoff M. & Labiouse V., 2011, *Technical Note: Preliminary estimation of rockfall runout zones*, Nat. Hazards Earth Syst. Sci., 11, 819-828, 2011

https://doi.org/10.5194/nhess-11-819-2011

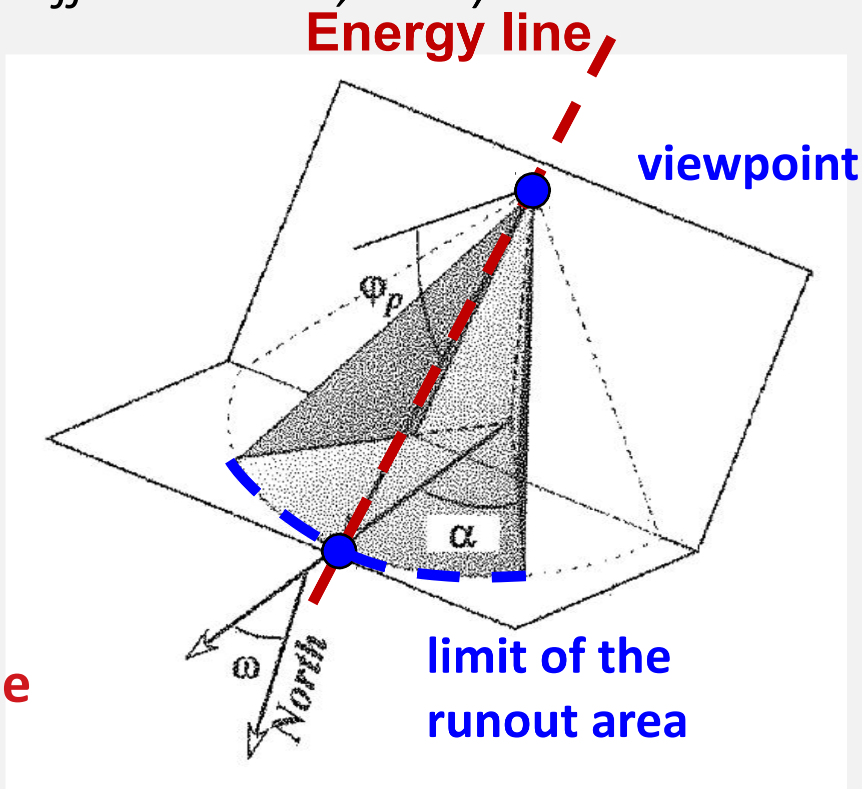
The *VIEWSHED function*



(Credit: innovativegis.com)

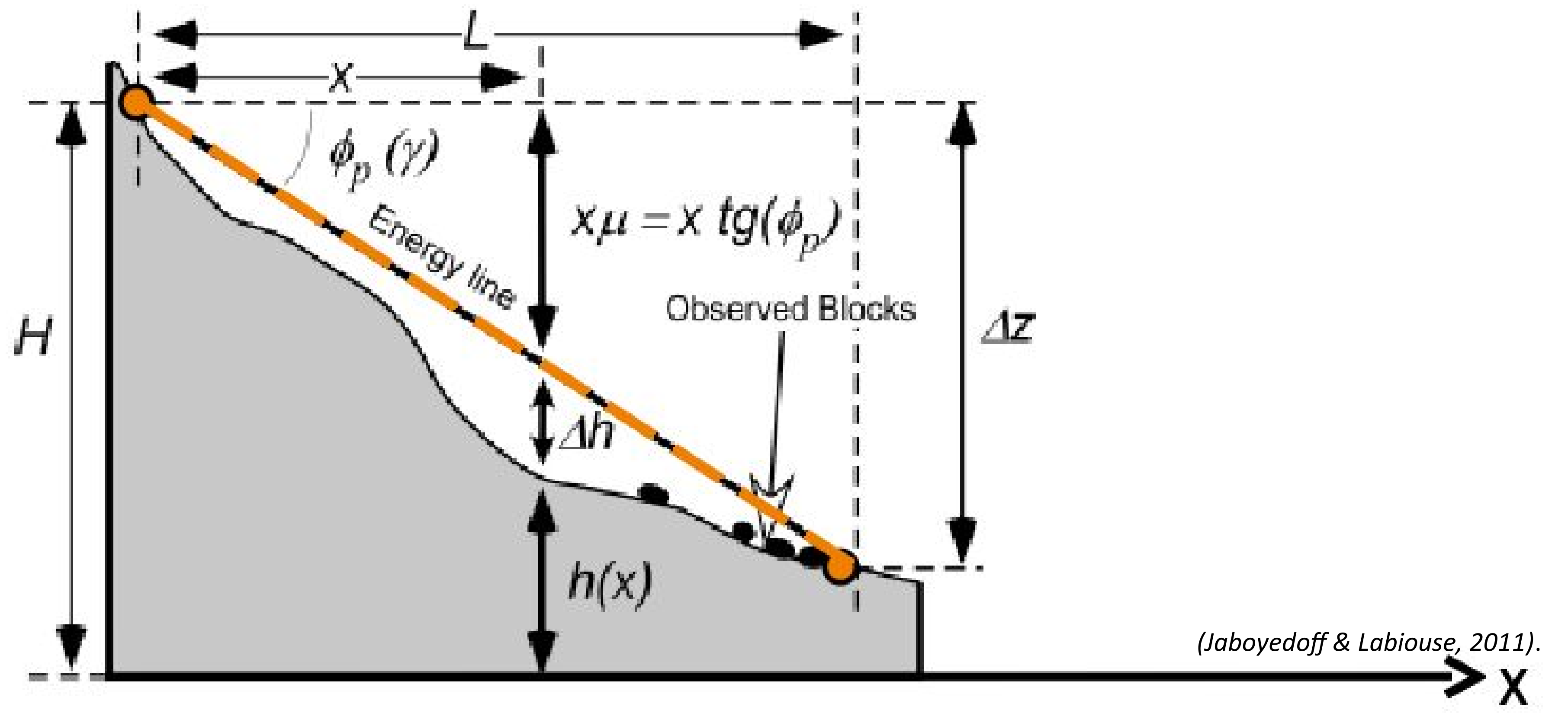
- Identifies the cells of a DTM visible to one or more observers (points of view)
- Calculates the number of observers who can see the same cell
- Every point of view becomes the apex of a "cone of visibility"

The Cone method *(Jaboyedoff & Labiouse, 2011)*



- ✔ An energy line represents the linear energy dissipation along the rockfall trajectory;
- ✔ The inclination of the energy line (φ_p) has the meaning of a **global friction angle**;
- ✔ The energy line inclination φ_p contributes to define the **visibility cone** in the vertical plane
- ✔ Two more angles are necessary to define the cone:
  - **ω** = dip direction
  - **2α** = aperture in the horizontal plane
- ✔ The intersection between the cone and the topographic surface defines the limit of the invasion zone

The Visibility Cone in vertical plane



(Jaboyedoff & Labiouse, 2011).

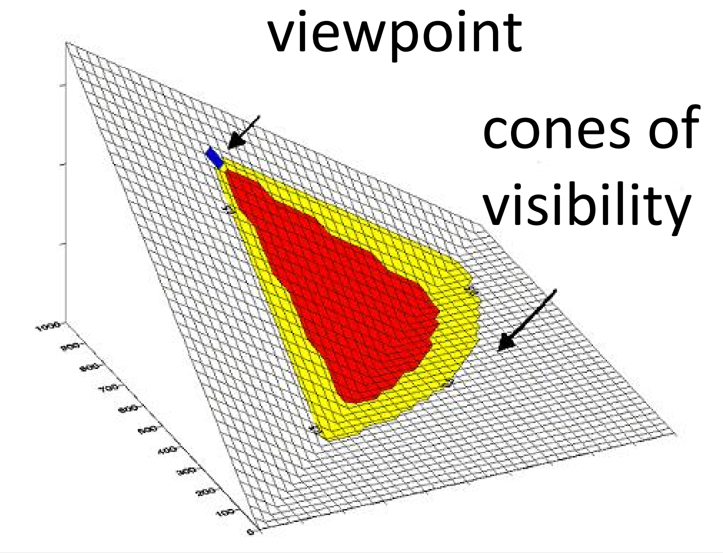
QPROTO - Q-GIS Predictive ROckfall TOol

- ✔ Estimation of the invasion zone of a rockfall phenomena on the basis of the **cone method** (*Jaboyedoff & Labiouse, 2011*)

- ✔ A ***Viewshed analysis*** (GRASS 7, GIS module) identifies the zones of an irregular surface (i.e. the cells of a DTM) that can be seen from one or more viewpoints

- ✔ Rockfall source points correspond to viewpoints and a 3D **"cone of visibility"** is associated to them by defining some limit angles

- ✔ Procedure created in **QGIS**, with the aim of promoting the diffusion of a open source tool easily accessible to professionals and administrators



(*Jaboyedoff & Labiouse, 2011*).

QPROTO - Q-GIS Predictive ROckfall TOol

Through an energy balance, it is possible to estimate **boulder velocity** for any (x, y, z) position below the energy line:

$$v(x,y) = \sqrt{2 \cdot g \cdot \left[H(x_0, y_0) - h(x,y) - \sqrt{(x-x_0)^2 + (y-y_0)^2} \cdot tan\varphi_p\right]}$$

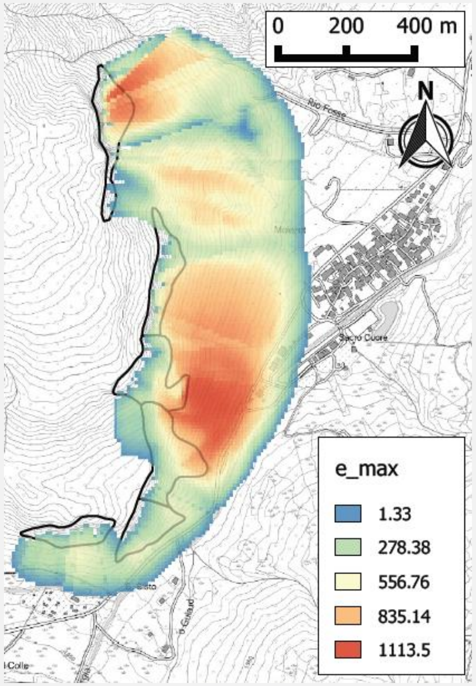
g = gravity acceleration

$x_{0,}$ y_0 = coordinates of the source point

$H(x_0,y_0)$ = elevation of the source point

$h(x,y)$ = elevation of the topographic surface at point (x,y)

φ_p = energy line angle



Hence **kinetic energy** can be estimated in any position:

$$E(x,y) = \frac{1}{2} \cdot m \cdot v^2(x,y)$$

m =mass of the boulder

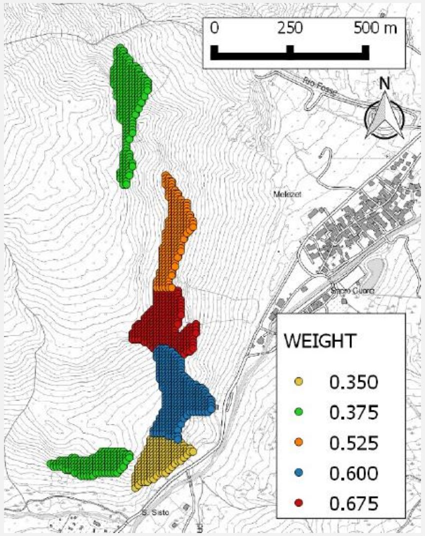
Maps of the mean and maximum value of the kinetic energy

QPROTO - Q-GIS Predictive ROckfall TOol

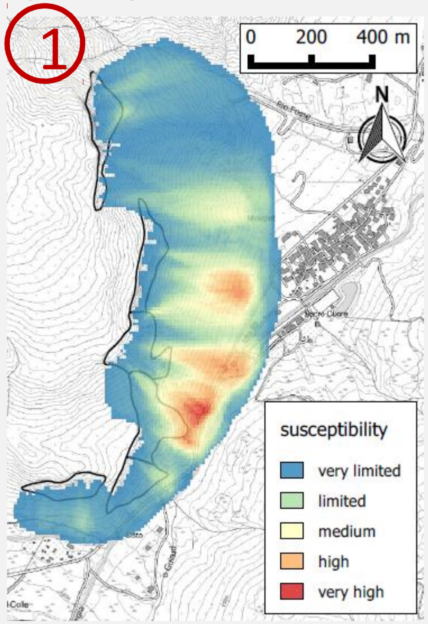
- ✔ A ***propensity to detachment*** **(I_D)** can be associated to each source, in terms of a weight
- ✔ It leads to calculate
  1) a weighted frequency map (susceptibility map)
  2) two relative (spatial) hazard maps

$$w\_en = [I_{D,i} \cdot E(x,y)_i]_{Max}$$

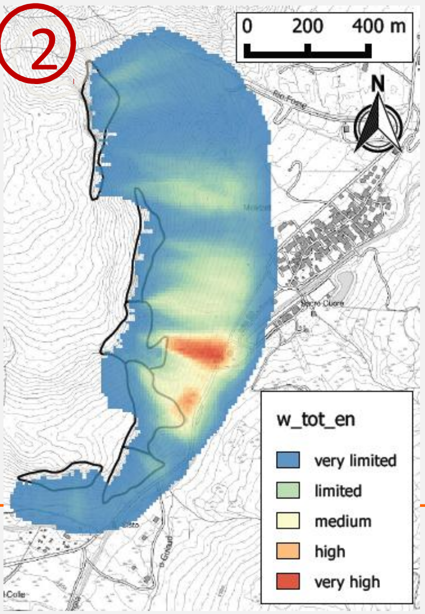
$$w\_tot\_en = \sum_{1}^{n} [I_{D,i} \cdot E(x,y)_i]$$



1



2

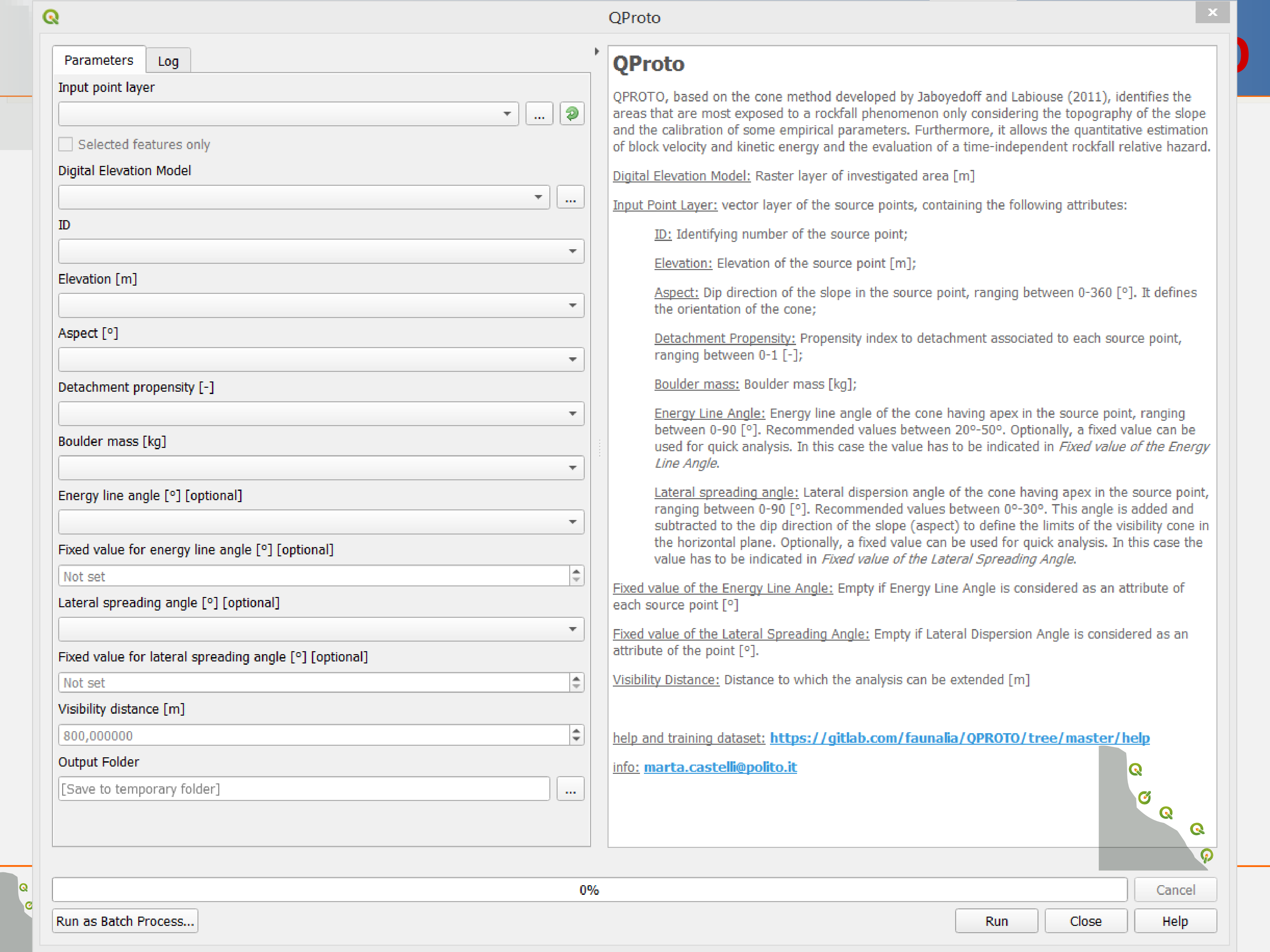


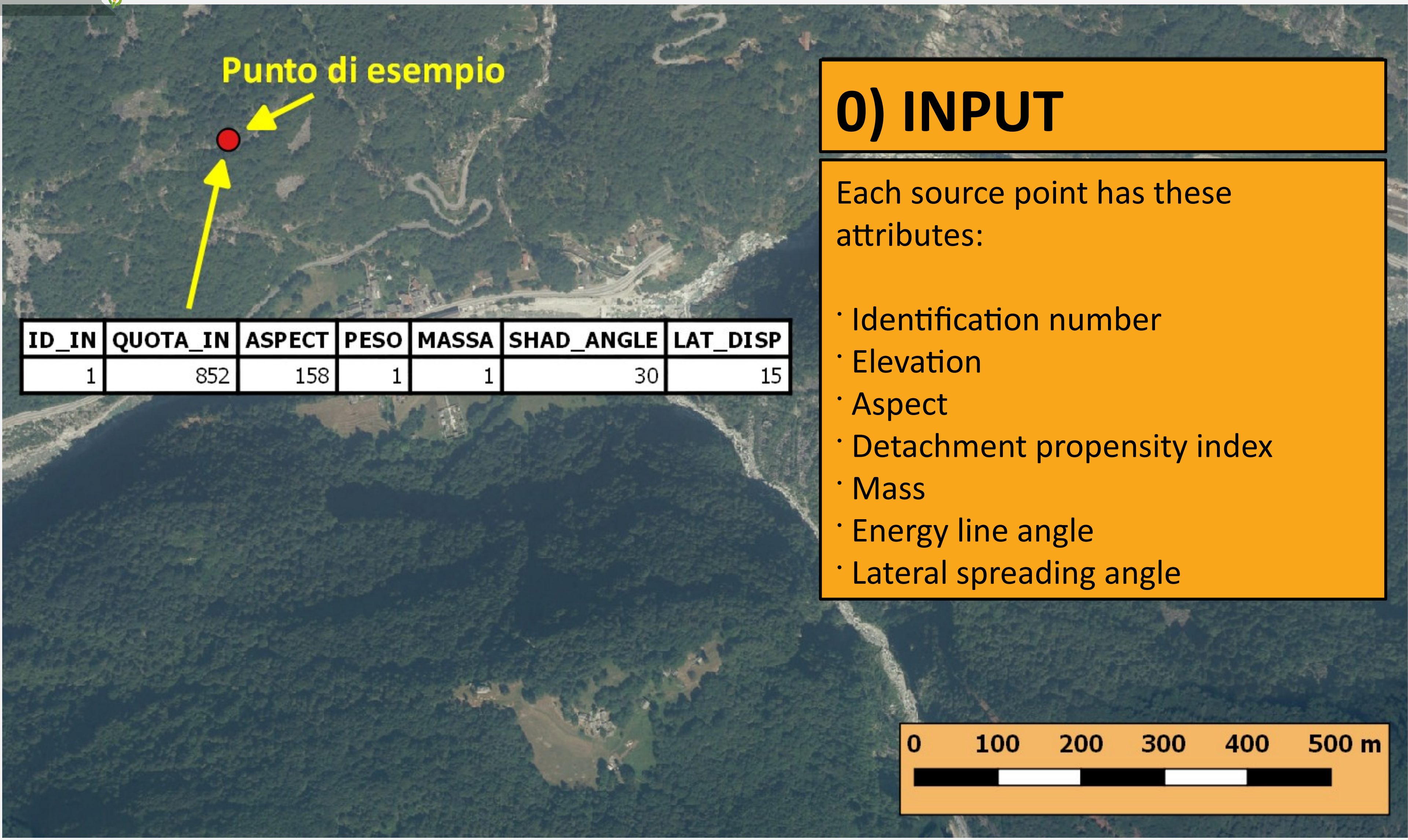
Castelli M., Grisolia M., Barbero M., Vallero G., Campus S., Pispico R. & Lanteri L., (2019), *A procedure to estimate rockfall hazard at a regional scale: the QPROTO tool.* (In preparation)

The code, written in **Python**, allows:

- the **calculation of the visibility function** for a set of source points (input vector layer)
- a series of elaborations related to all the simulated visibility cones

The method uses algorithms from third part providers that can be called by QGIS (GRASS r.viewshed, SAGA) to evaluate **the runout area, velocity and energy values at each point of the runout area** (minimum, maximum and mean velocity and energy).


QProto
Parameters
Log
Input point layer
...
Selected features only
Digital Elevation Model
...
ID
Elevation [m]
Aspect [°]
Detachment propensity [-]
Boulder mass [kg]
Energy line angle [°] [optional]
Fixed value for energy line angle [°] [optional]
Not set
Lateral spreading angle [°] [optional]
Fixed value for lateral spreading angle [°] [optional]
Not set
Visibility distance [m]
800,000000
Output Folder
[Save to temporary folder]
...
QProto
QPROTO, based on the cone method developed by Jaboyedoff and Labiouse (2011), identifies the areas that are most exposed to a rockfall phenomenon only considering the topography of the slope and the calibration of some empirical parameters. Furthermore, it allows the quantitative estimation of block velocity and kinetic energy and the evaluation of a time-independent rockfall relative hazard.
Digital Elevation Model: Raster layer of investigated area [m]
Input Point Layer: vector layer of the source points, containing the following attributes:
ID: Identifying number of the source point;
Elevation: Elevation of the source point [m];
Aspect: Dip direction of the slope in the source point, ranging between 0-360 [°]. It defines the orientation of the cone;
Detachment Propensity: Propensity index to detachment associated to each source point, ranging between 0-1 [-];
Boulder mass: Boulder mass [kg];
Energy Line Angle: Energy line angle of the cone having apex in the source point, ranging between 0-90 [°]. Recommended values between 20°-50°. Optionally, a fixed value can be used for quick analysis. In this case the value has to be indicated in Fixed value of the Energy Line Angle.
Lateral spreading angle: Lateral dispersion angle of the cone having apex in the source point, ranging between 0-90 [°]. Recommended values between 0°-30°. This angle is added and subtracted to the dip direction of the slope (aspect) to define the limits of the visibility cone in the horizontal plane. Optionally, a fixed value can be used for quick analysis. In this case the value has to be indicated in Fixed value of the Lateral Spreading Angle.
Fixed value of the Energy Line Angle: Empty if Energy Line Angle is considered as an attribute of each source point [°]
Fixed value of the Lateral Spreading Angle: Empty if Lateral Dispersion Angle is considered as an attribute of the point [°].
Visibility Distance: Distance to which the analysis can be extended [m]
help and training dataset: https://gitlab.com/faunalia/QPROTO/tree/master/help
info: marta.castelli@polito.it
0%
Cancel
Run as Batch Process...
Run
Close
Help

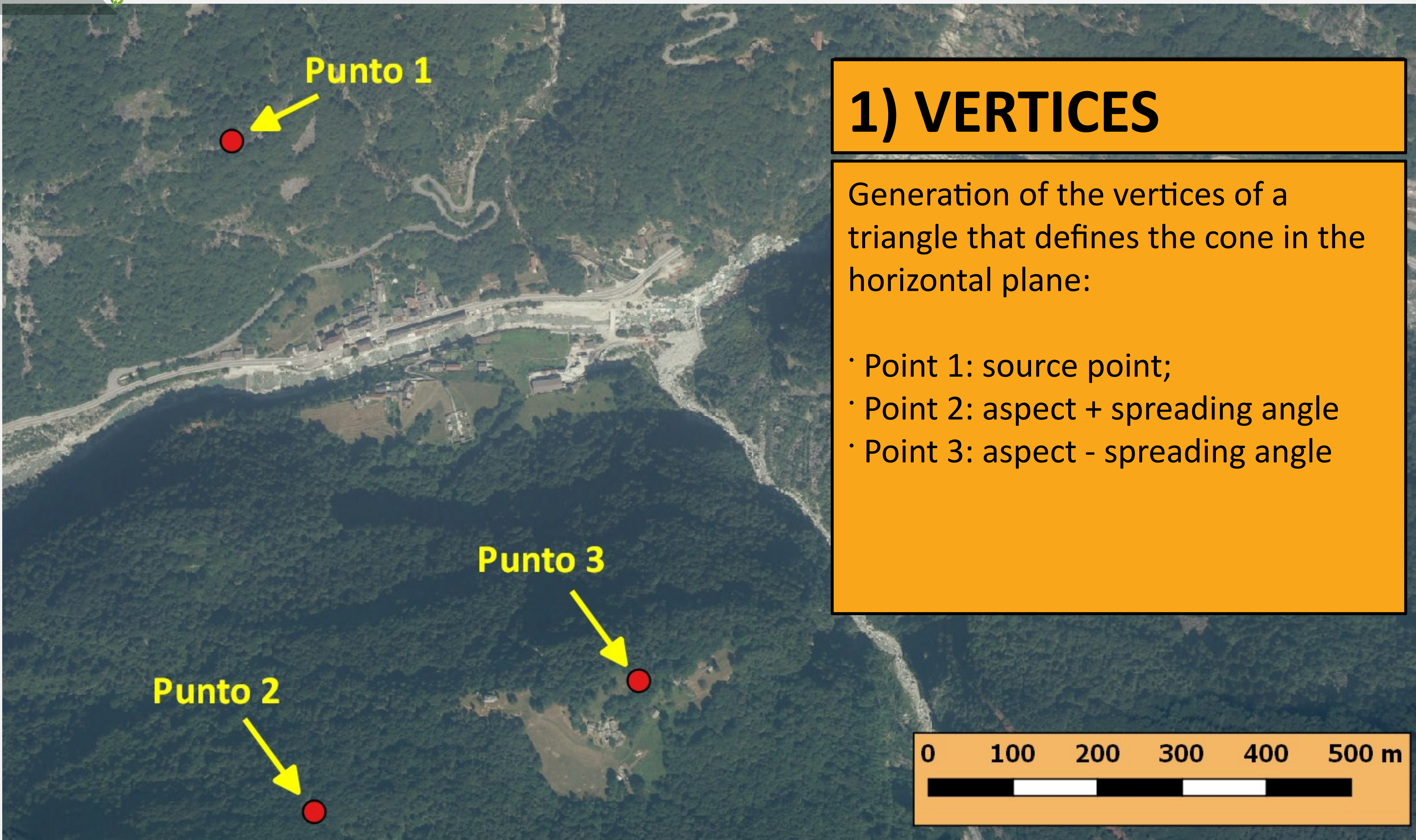


ID_IN	QUOTA_IN	ASPECT	PESO	MASSA	SHAD_ANGLE	LAT_DISP
1	852	158	1	1	30	15

0) INPUT

Each source point has these attributes:

- Identification number
- Elevation
- Aspect
- Detachment propensity index
- Mass
- Energy line angle
- Lateral spreading angle



1) VERTICES

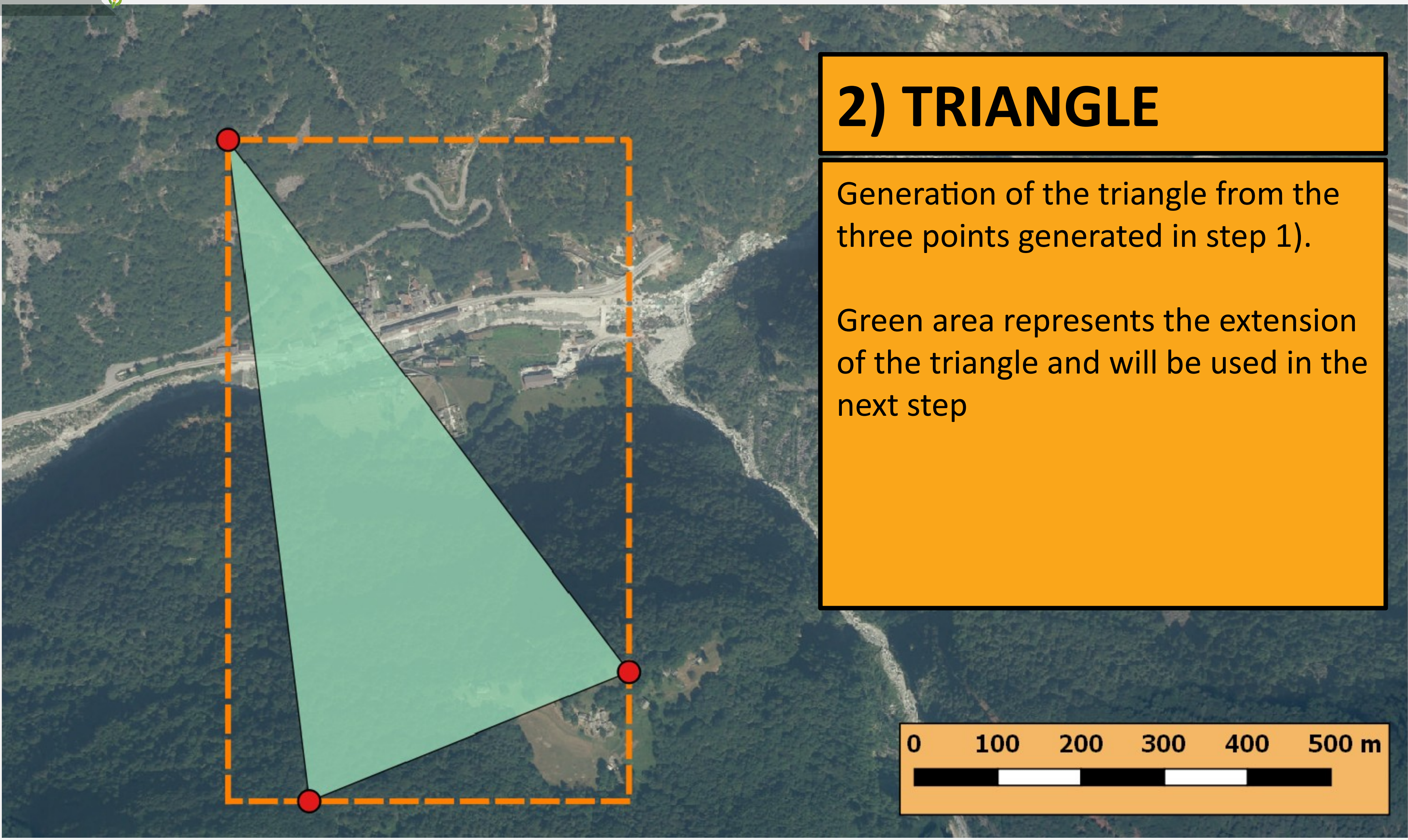
Generation of the vertices of a triangle that defines the cone in the horizontal plane:

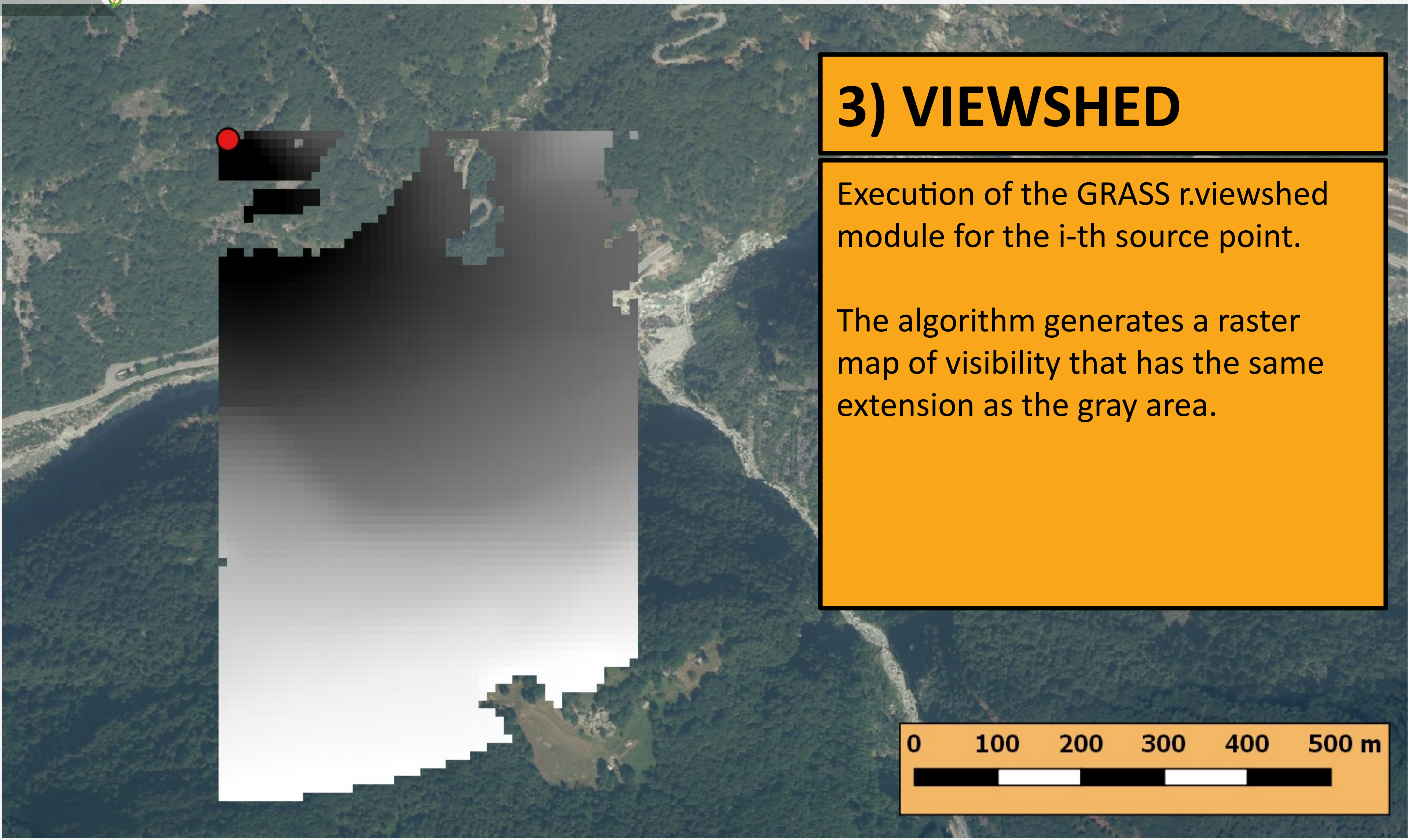
- Point 1: source point;
- Point 2: aspect + spreading angle
- Point 3: aspect - spreading angle

2) TRIANGLE

Generation of the triangle from the three points generated in step 1).

Green area represents the extension of the triangle and will be used in the next step





3) VIEWSHED

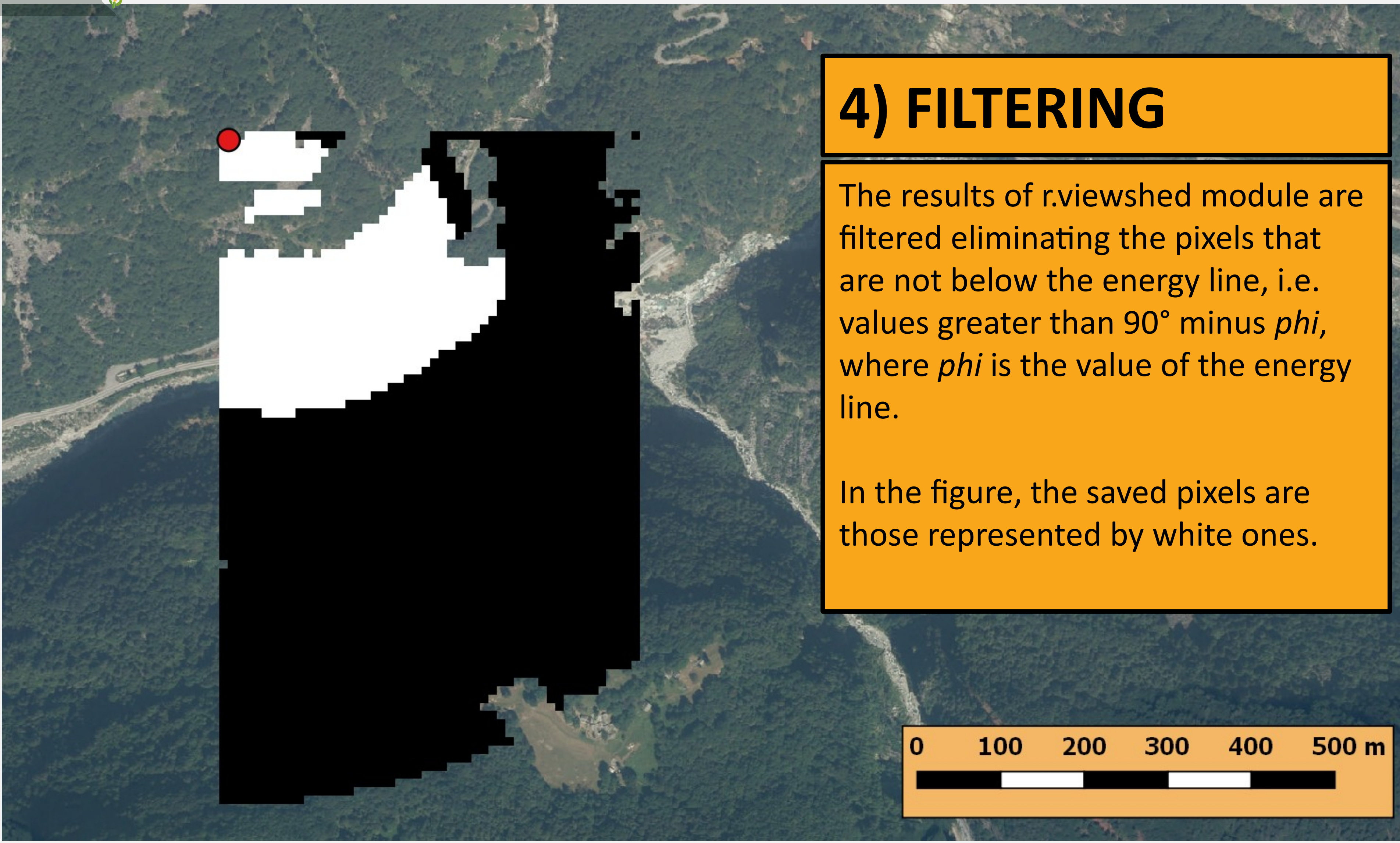
Execution of the GRASS r.viewshed module for the i-th source point.

The algorithm generates a raster map of visibility that has the same extension as the gray area.

4) FILTERING

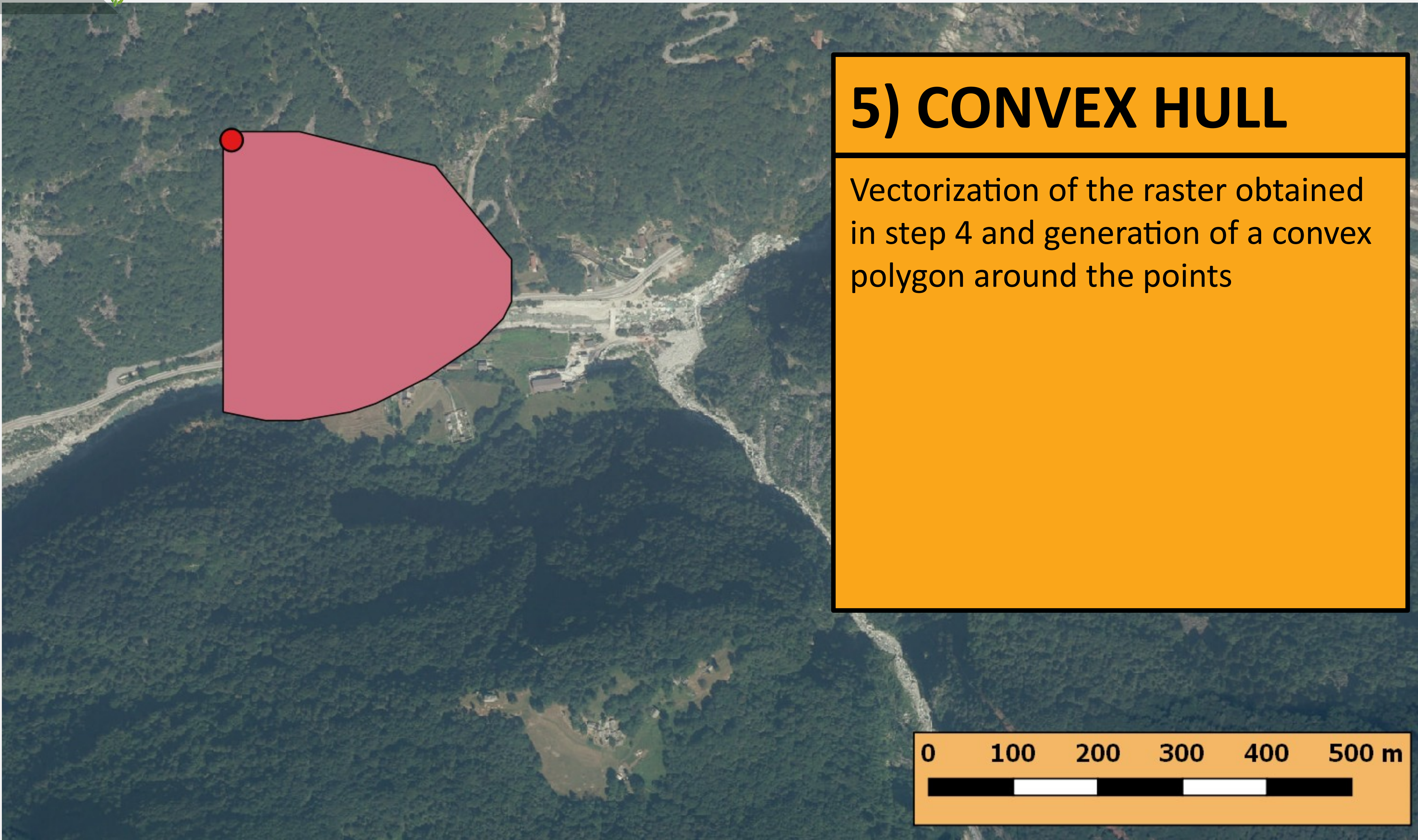
The results of r.viewshed module are filtered eliminating the pixels that are not below the energy line, i.e. values greater than 90° minus *phi*, where *phi* is the value of the energy line.

In the figure, the saved pixels are those represented by white ones.



5) CONVEX HULL

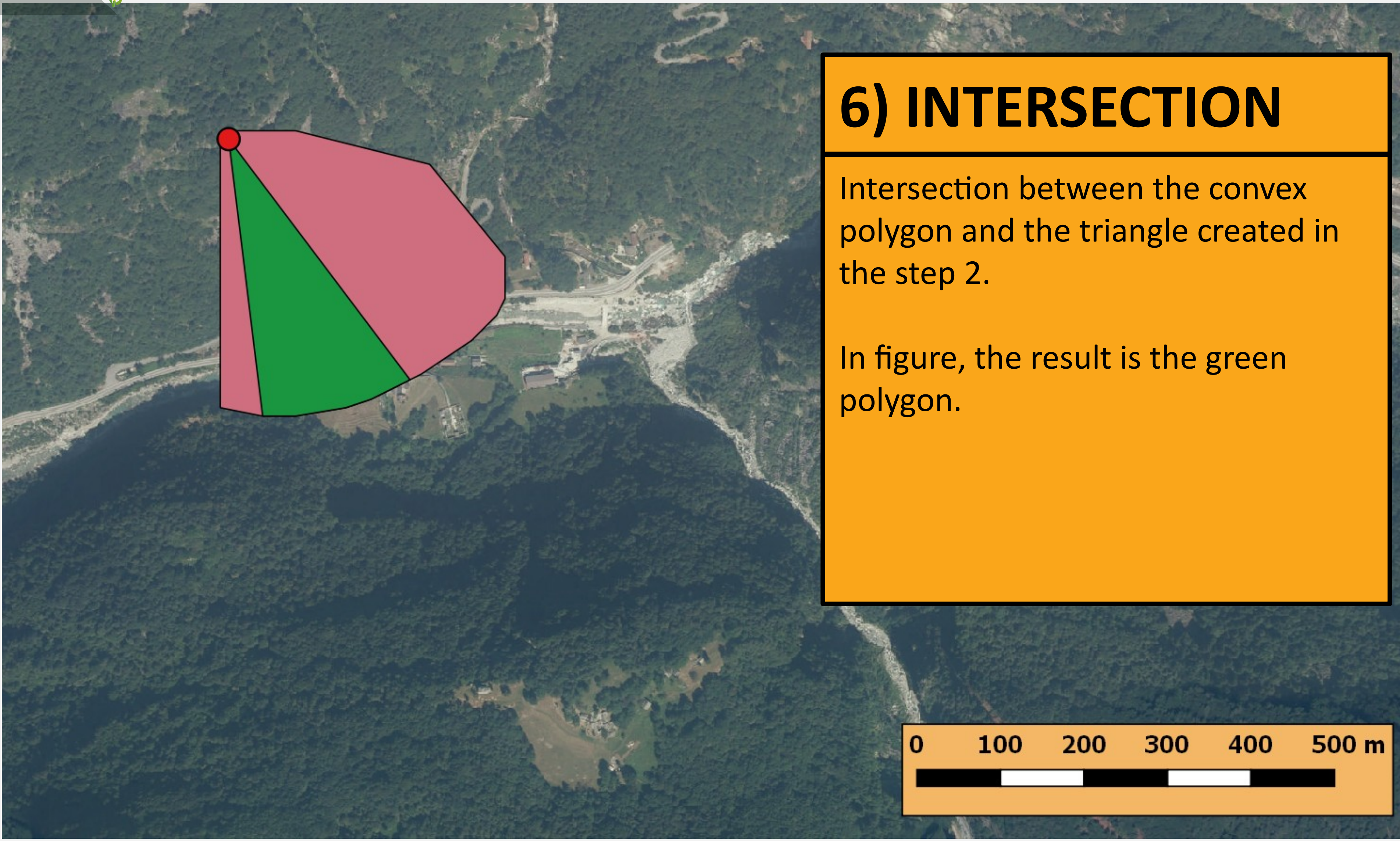
Vectorization of the raster obtained in step 4 and generation of a convex polygon around the points

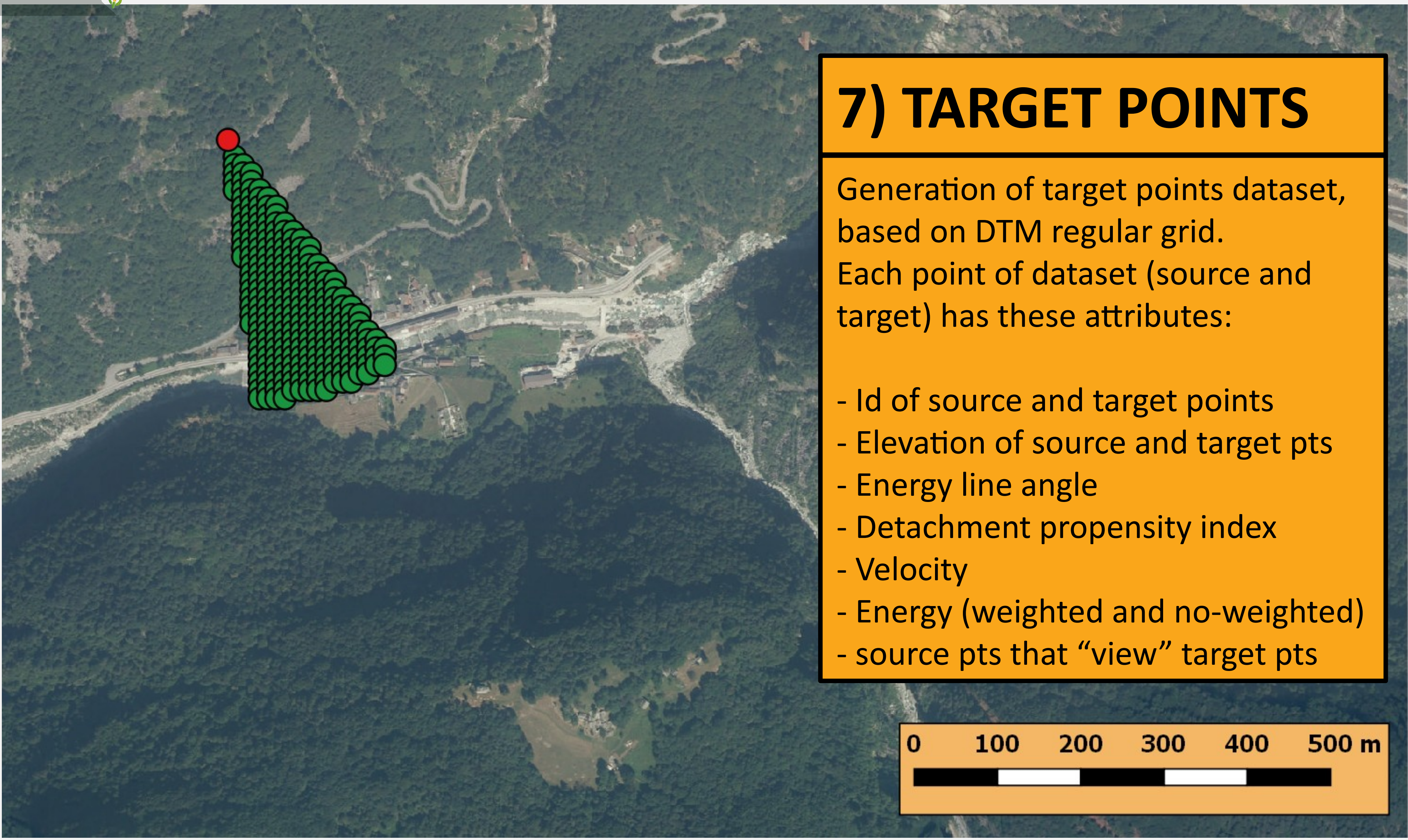


6) INTERSECTION

Intersection between the convex polygon and the triangle created in the step 2.

In figure, the result is the green polygon.

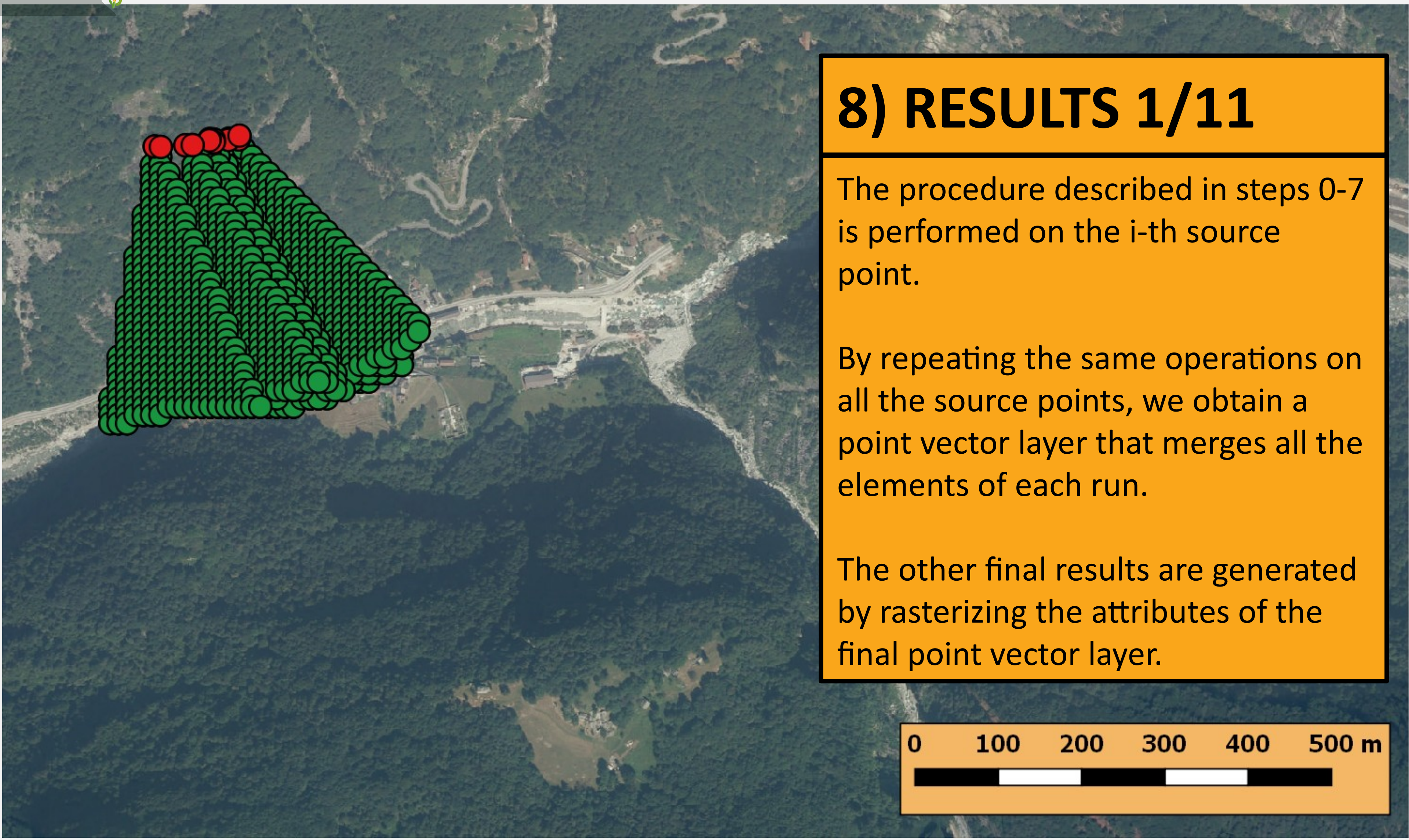




7) TARGET POINTS

Generation of target points dataset, based on DTM regular grid.
Each point of dataset (source and target) has these attributes:

- Id of source and target points
- Elevation of source and target pts
- Energy line angle
- Detachment propensity index
- Velocity
- Energy (weighted and no-weighted)
- source pts that “view” target pts



8) RESULTS 1/11

The procedure described in steps 0-7 is performed on the i-th source point.

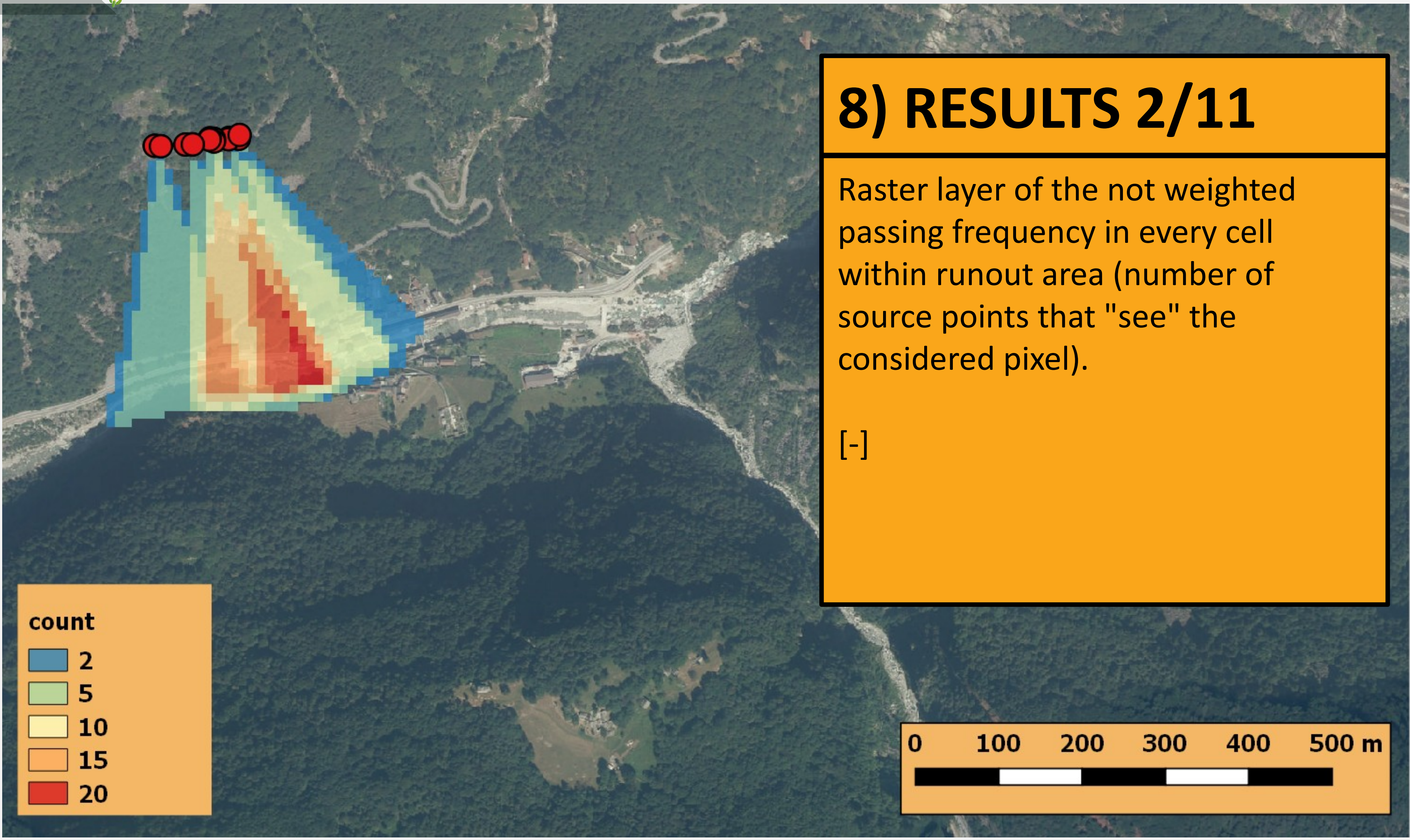
By repeating the same operations on all the source points, we obtain a point vector layer that merges all the elements of each run.

The other final results are generated by rasterizing the attributes of the final point vector layer.

8) RESULTS 2/11

Raster layer of the not weighted passing frequency in every cell within runout area (number of source points that "see" the considered pixel).

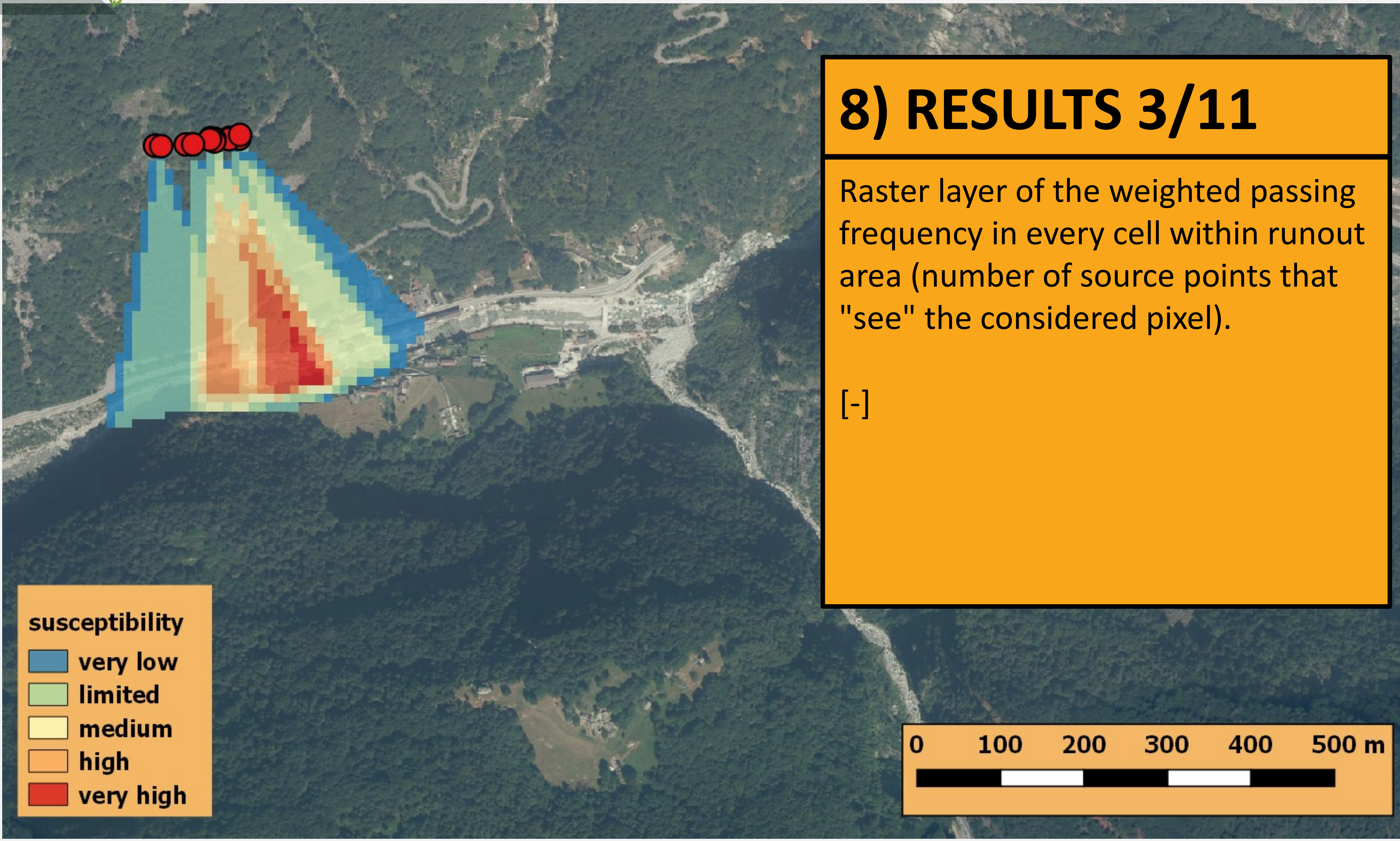
[-]



8) RESULTS 3/11

Raster layer of the weighted passing frequency in every cell within runout area (number of source points that "see" the considered pixel).

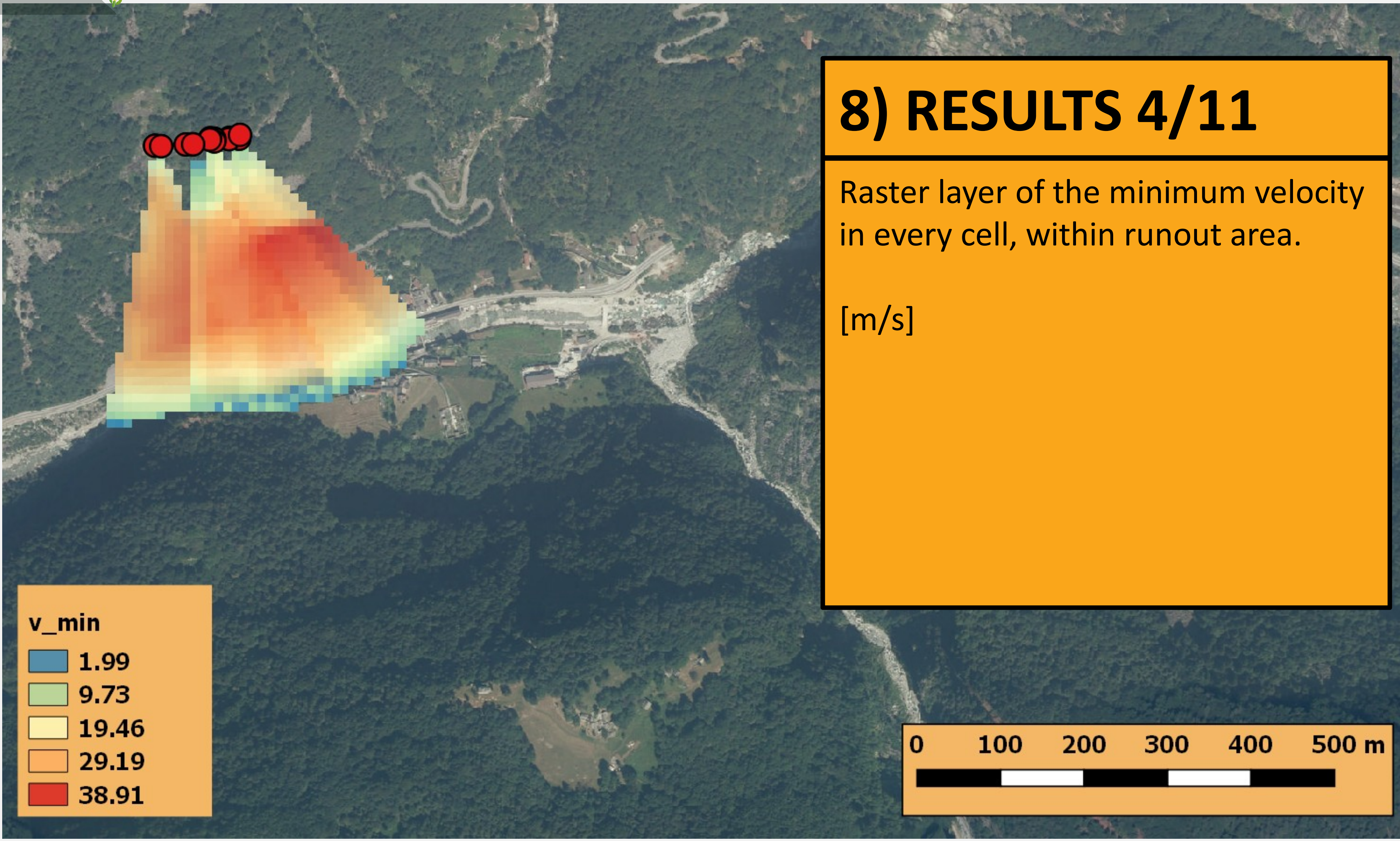
[-]



8) RESULTS 4/11

Raster layer of the minimum velocity in every cell, within runout area.

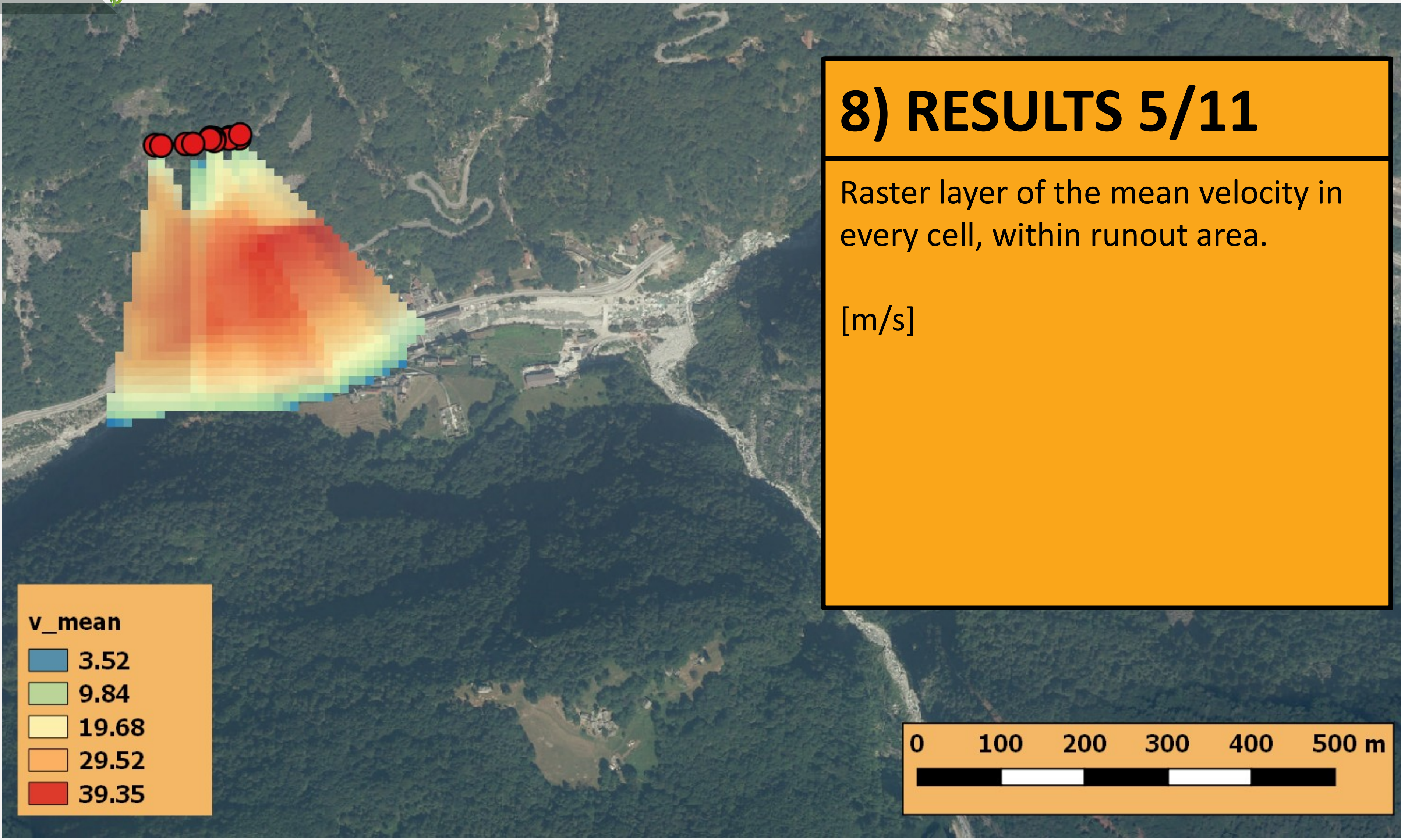
[m/s]

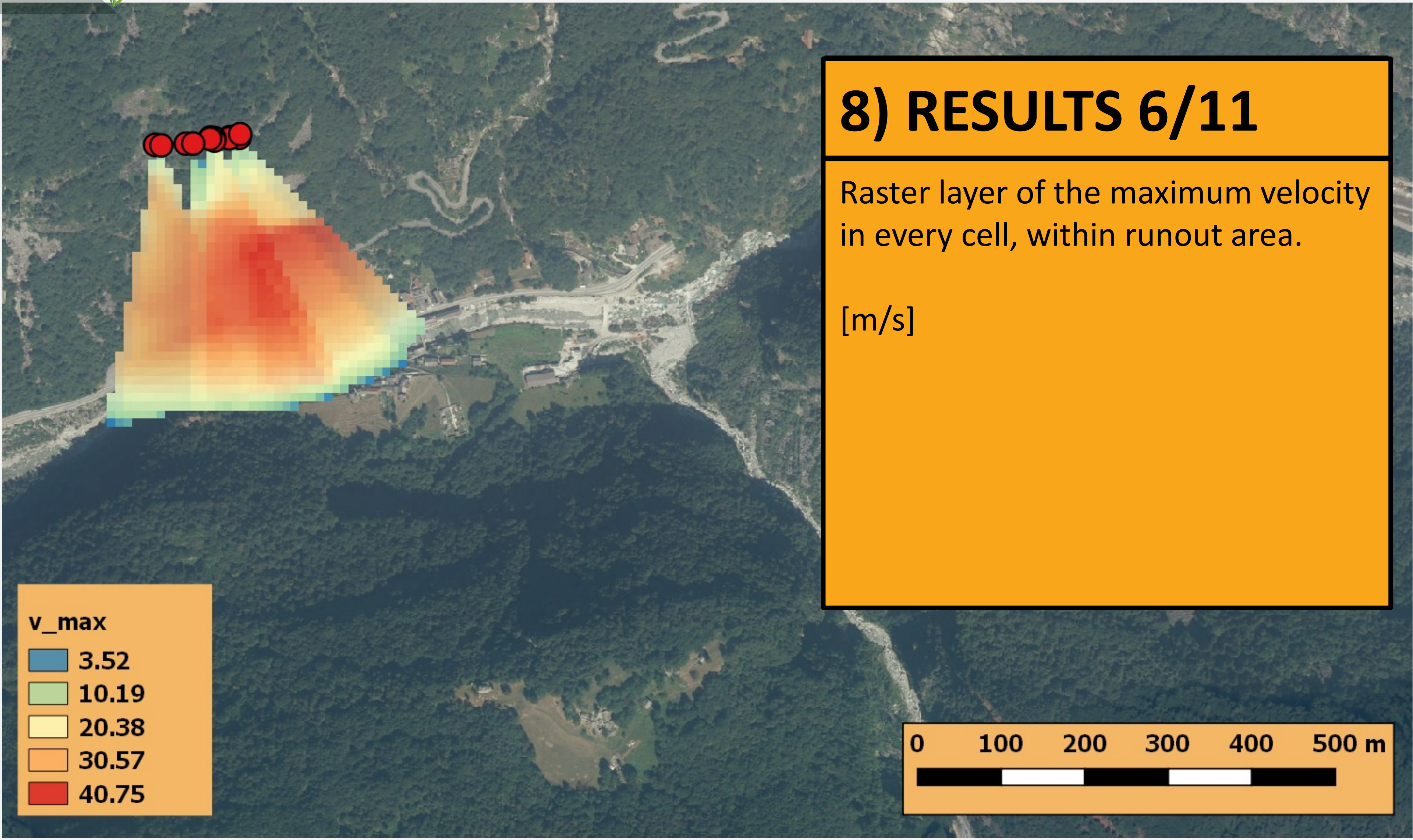


8) RESULTS 5/11

Raster layer of the mean velocity in every cell, within runout area.

[m/s]





8) RESULTS 6/11

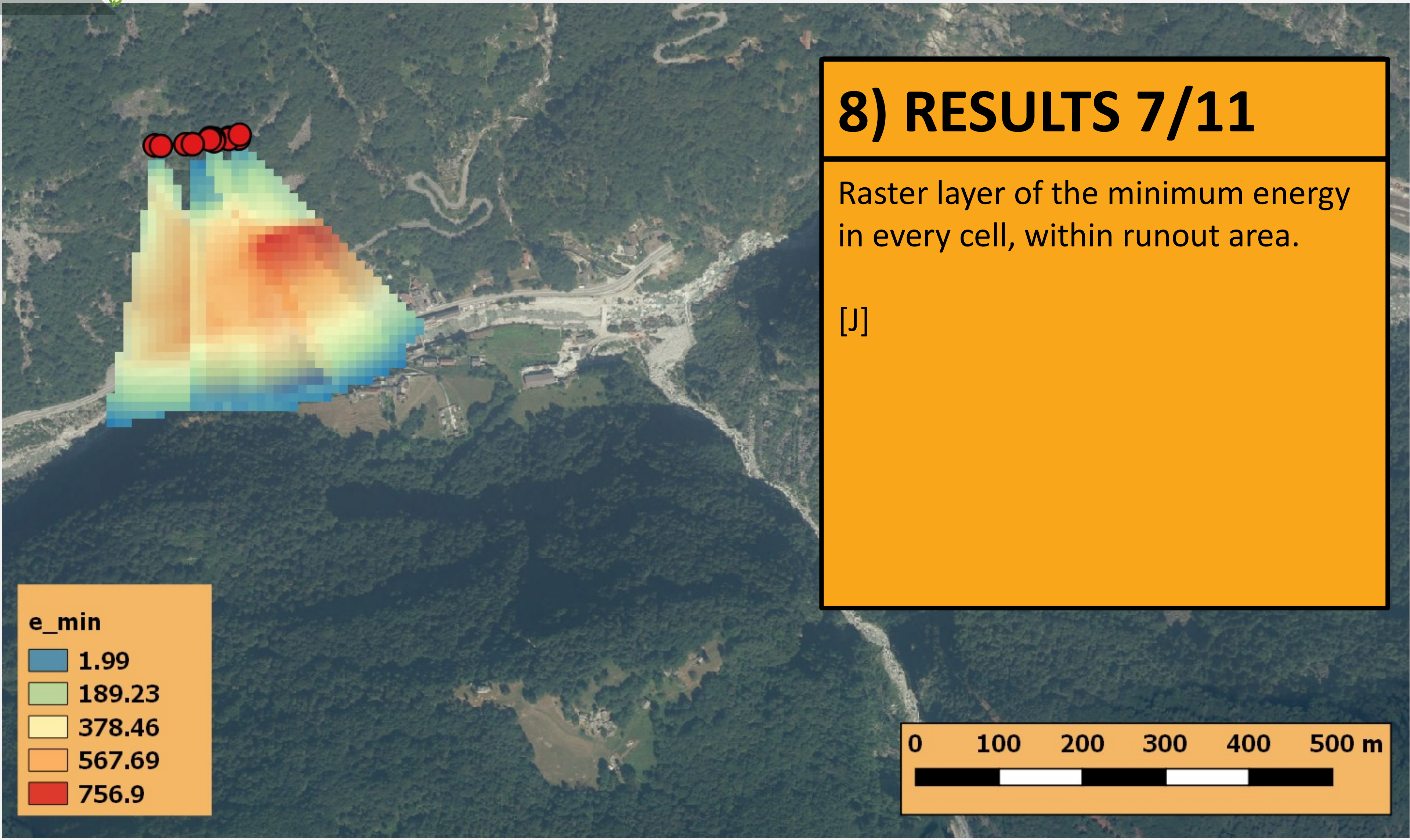
Raster layer of the maximum velocity in every cell, within runout area.

[m/s]

8) RESULTS 7/11

Raster layer of the minimum energy in every cell, within runout area.

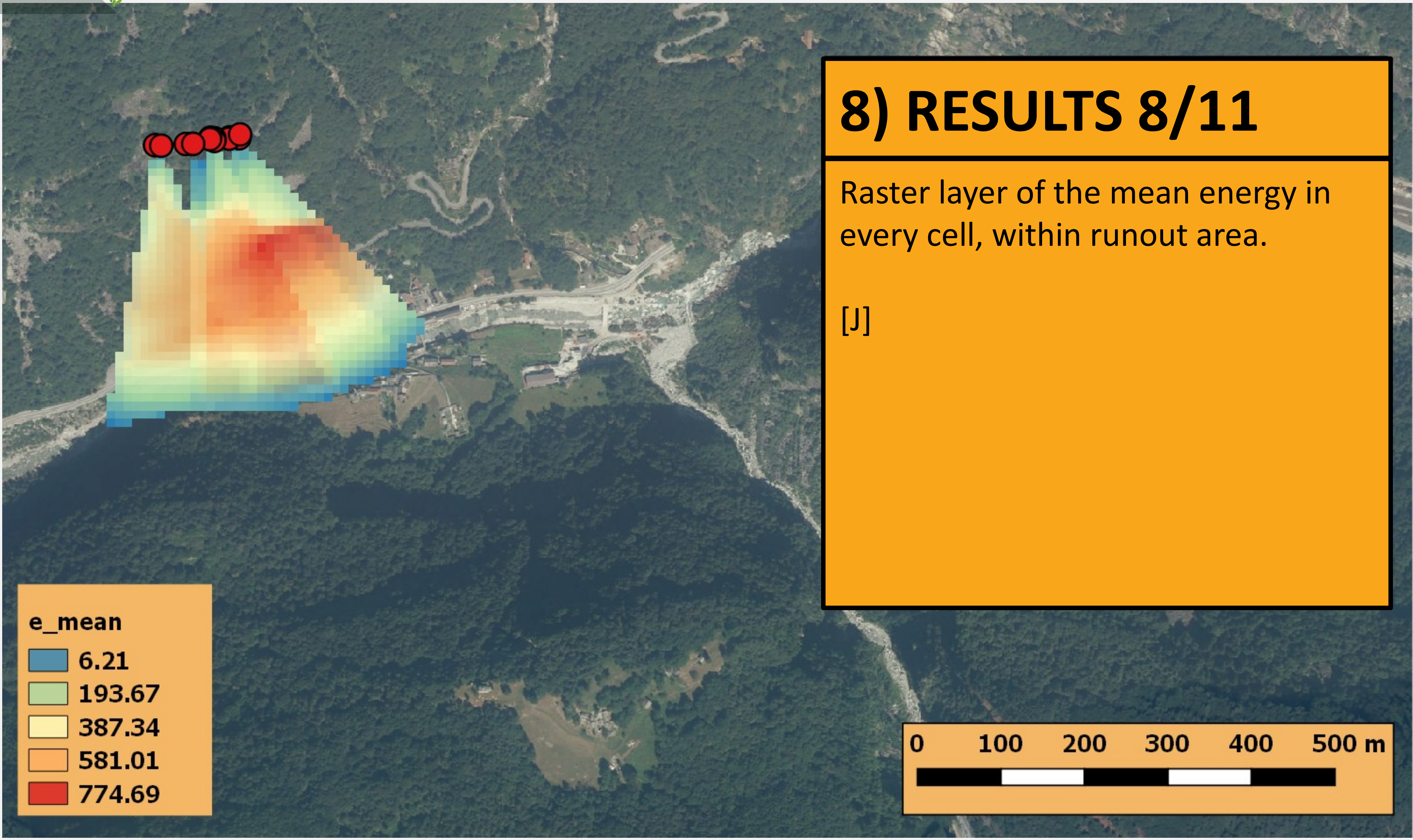
[J]



8) RESULTS 8/11

Raster layer of the mean energy in every cell, within runout area.

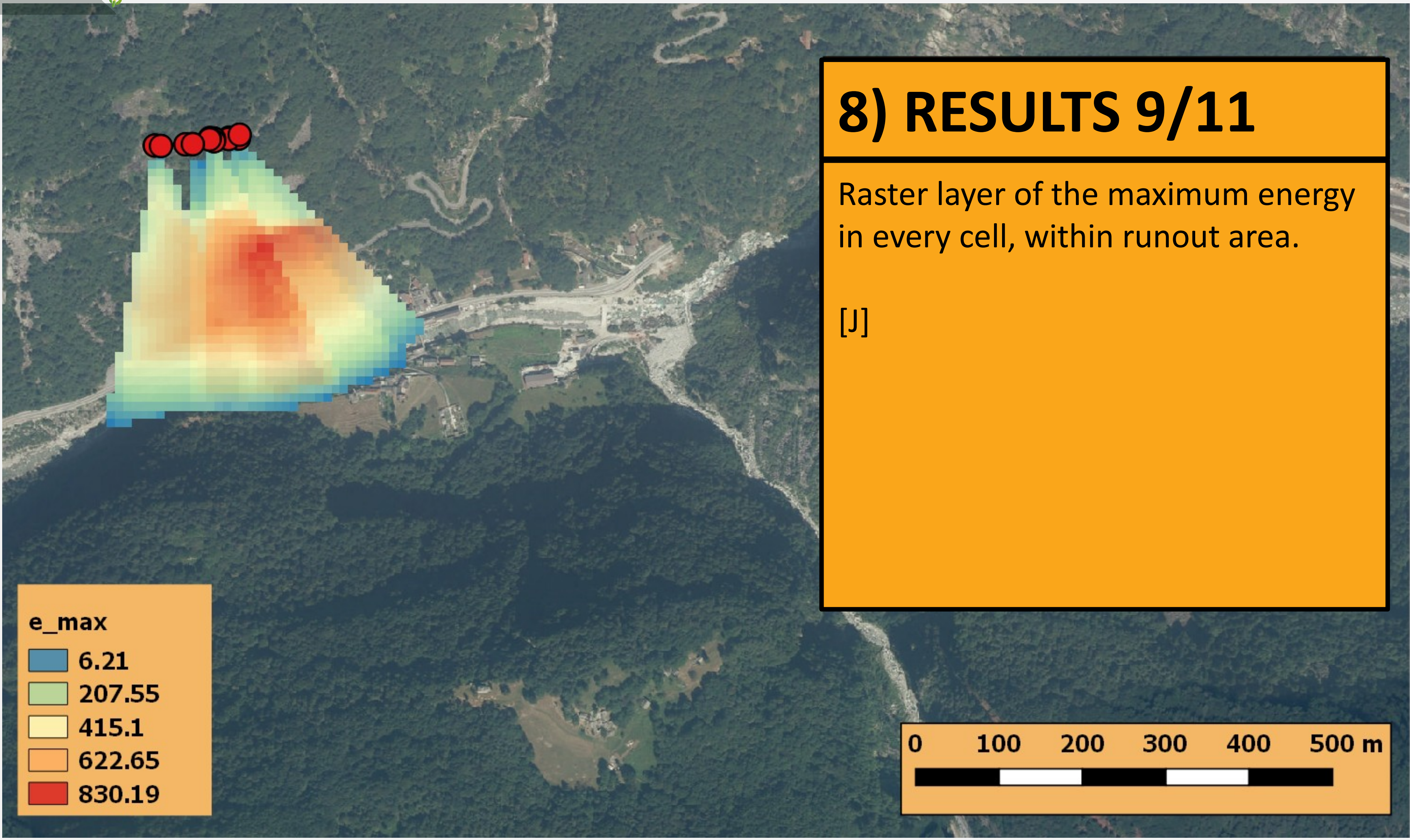
[J]



8) RESULTS 9/11

Raster layer of the maximum energy in every cell, within runout area.

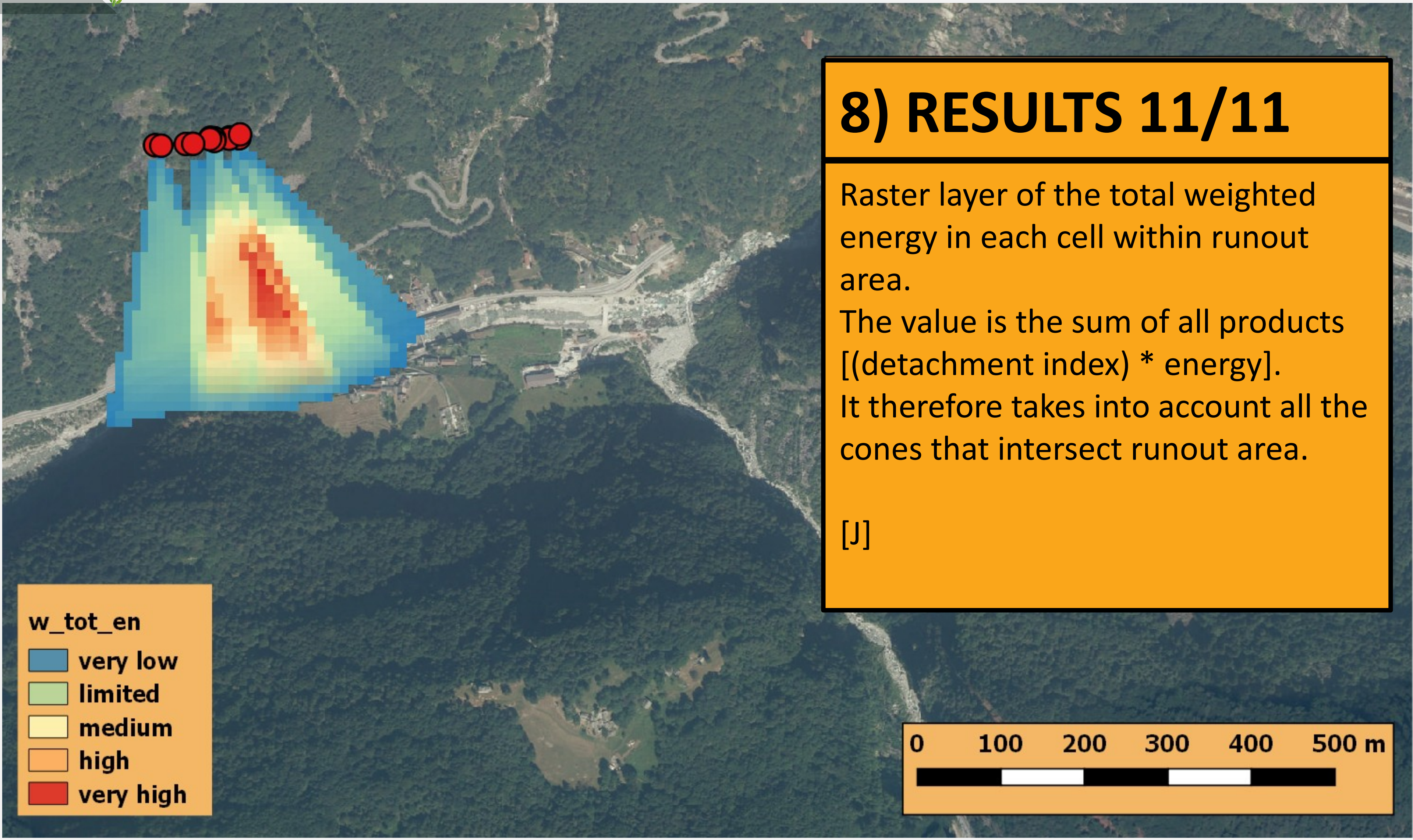
[J]



8) RESULTS 11/11

Raster layer of the total weighted energy in each cell within runout area.
The value is the sum of all products [(detachment index) * energy].
It therefore takes into account all the cones that intersect runout area.

[J]

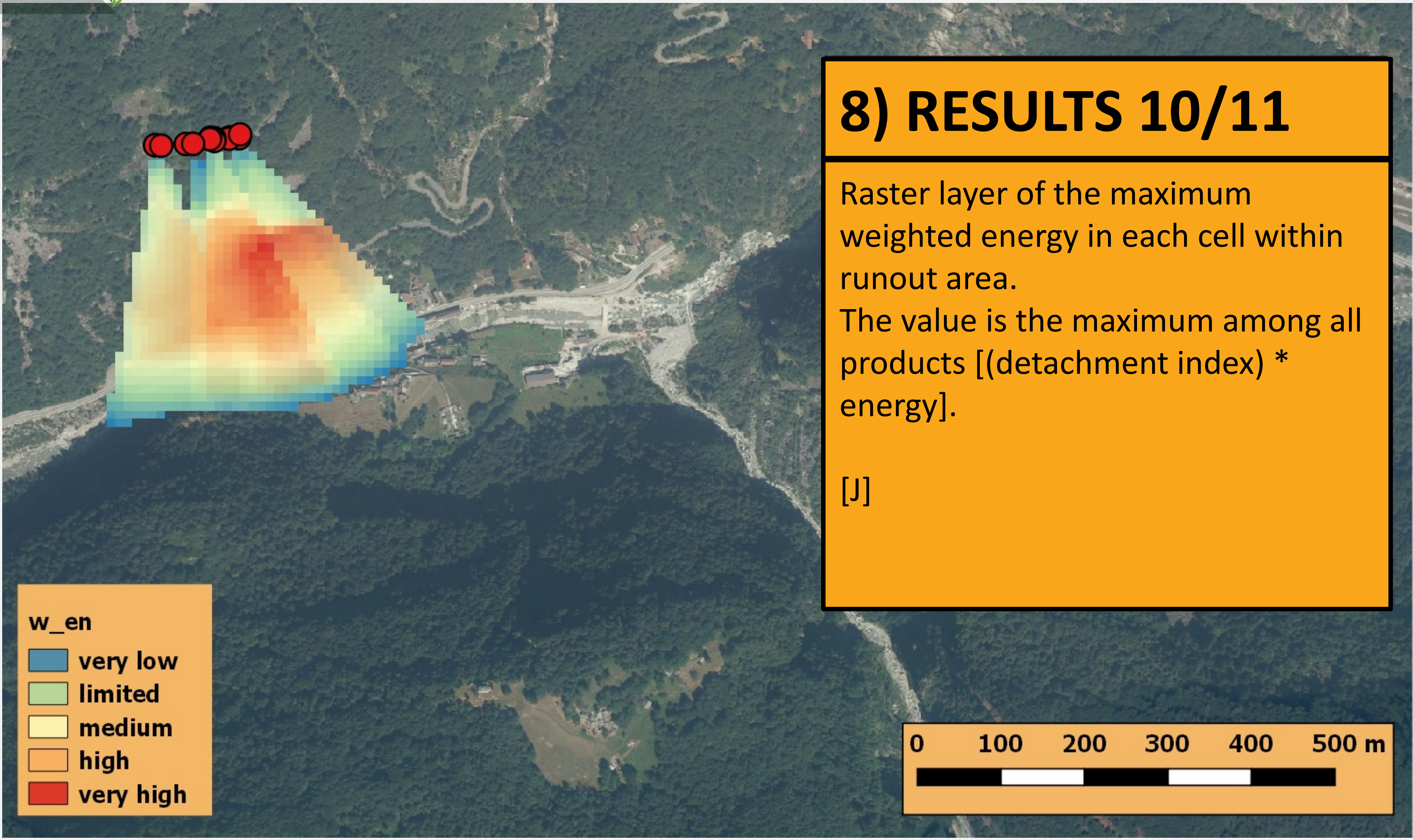


8) RESULTS 10/11

Raster layer of the maximum weighted energy in each cell within runout area.

The value is the maximum among all products [(detachment index) * energy].

[J]



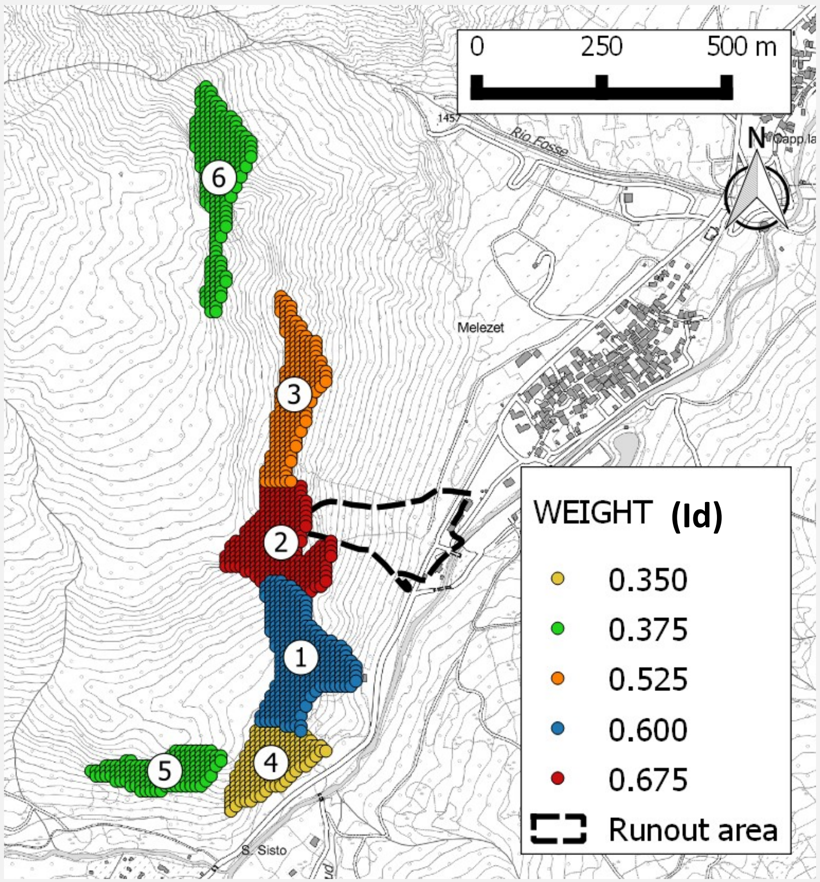
CASE HISTORY

Example of application of QPROTO on a slope in the Melezet hamlet, Municipality of Bardonecchia, near Torino (NW Italy).

The analysis was carried out on a **10 x 10 m² DTM** and **1349 source points**.

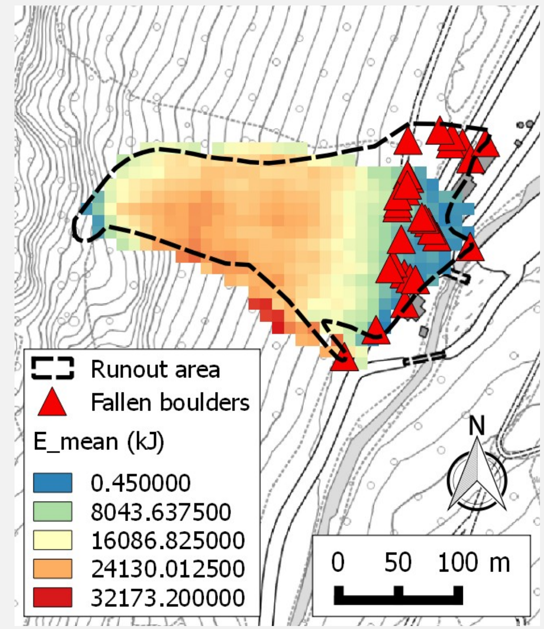
All the blocks have **1 kg mass** and the **detachment propensity index is spatially variable between 0.350 and 0.675**, while the value of the **energy line angle is constant and equals to 35°** (from back analysis). Moreover, it has been set an **angular dispersion on the horizontal plane equals to of ± 10°** and **800 m for propagation distance.**

SOURCE POINTS



(source points)

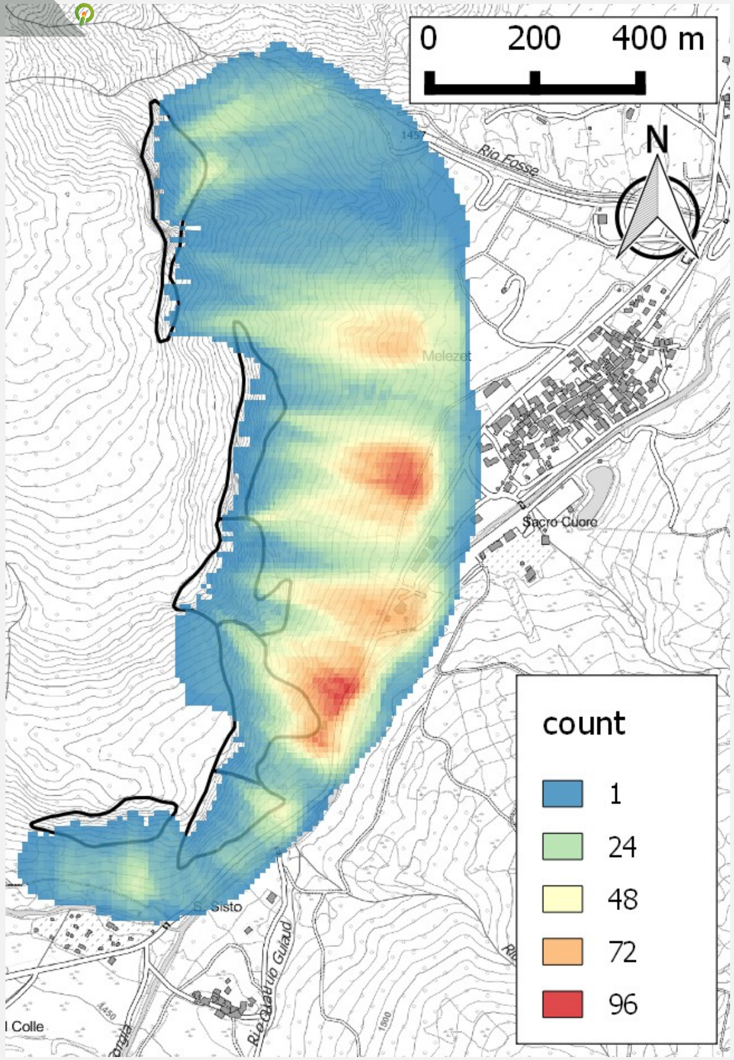
BACK ANALYSIS



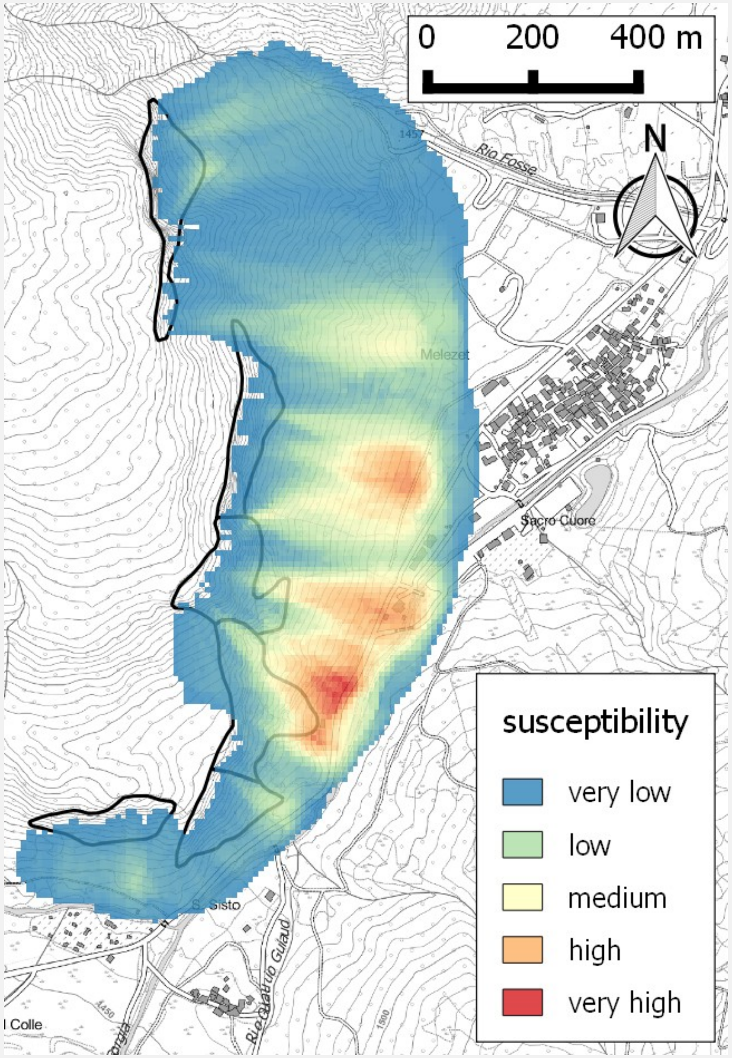
$\varphi_p = 35°$

$\alpha = \pm 10°$

CASE HISTORY

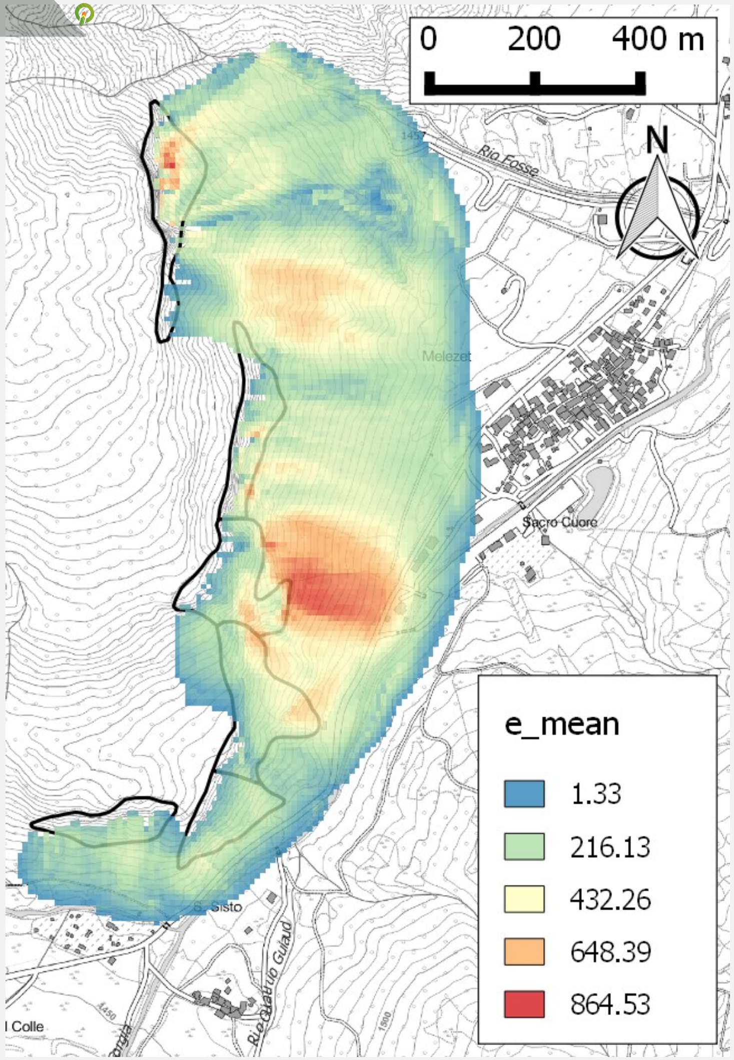


(Raster layer of the not-weighted passing frequency in every cell within runout area)

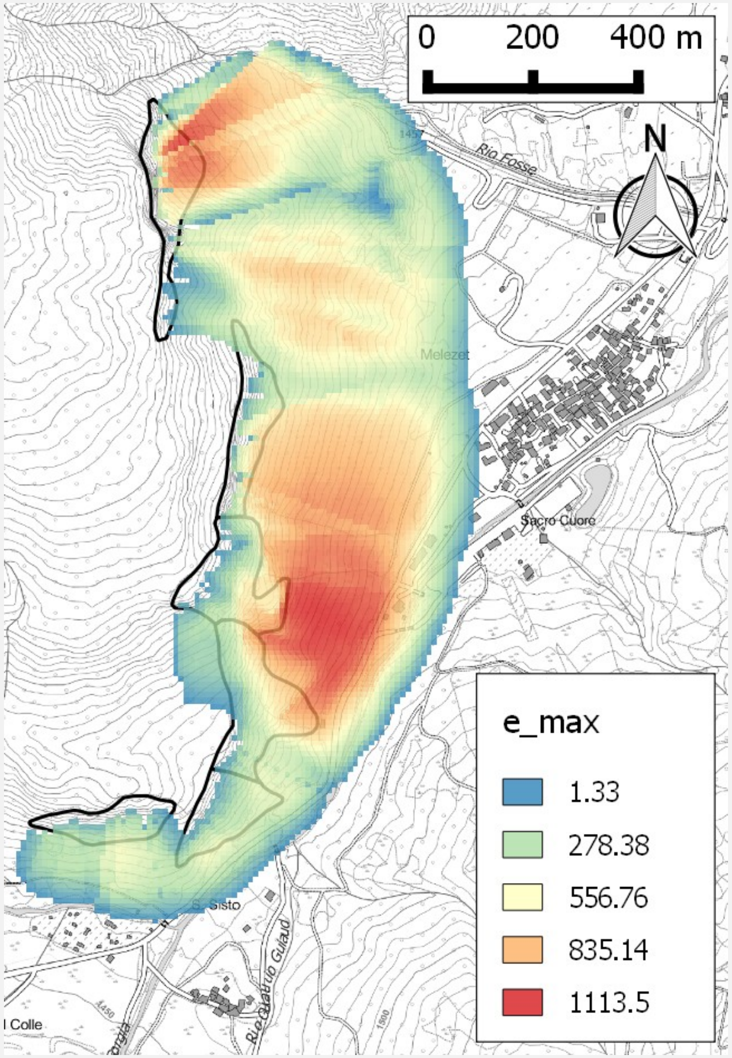


(Raster layer of the weighted passing frequency in every cell within runout area)

CASE HISTORY

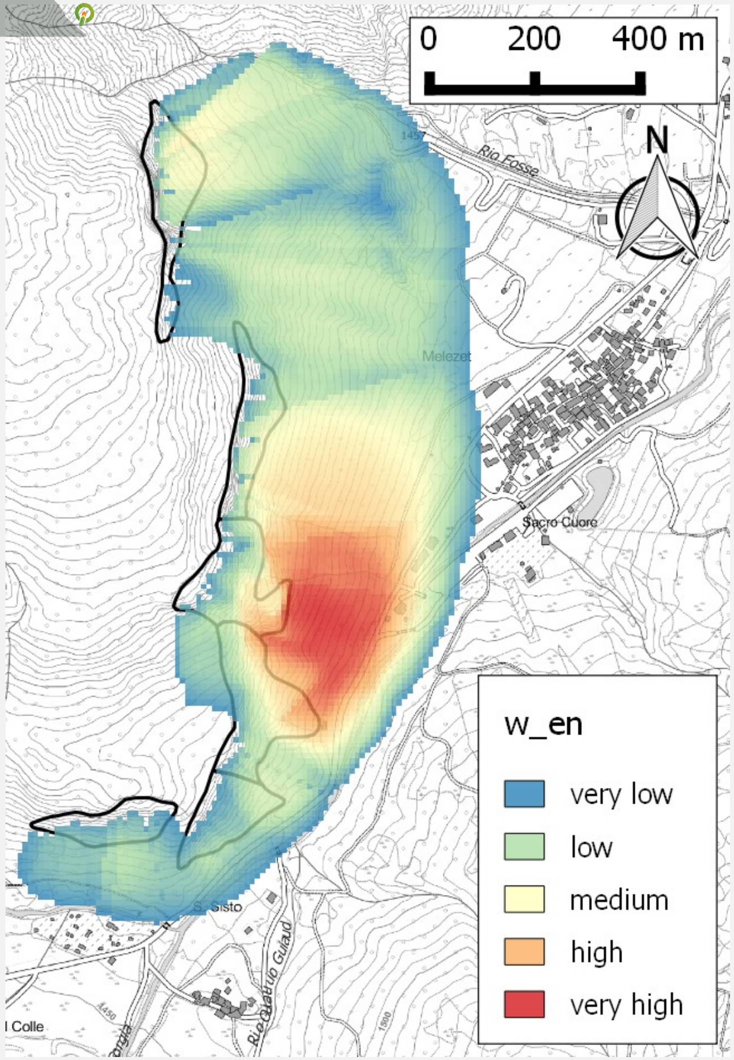


(Raster layer of the mean energy in every cell, within runout area. [J])

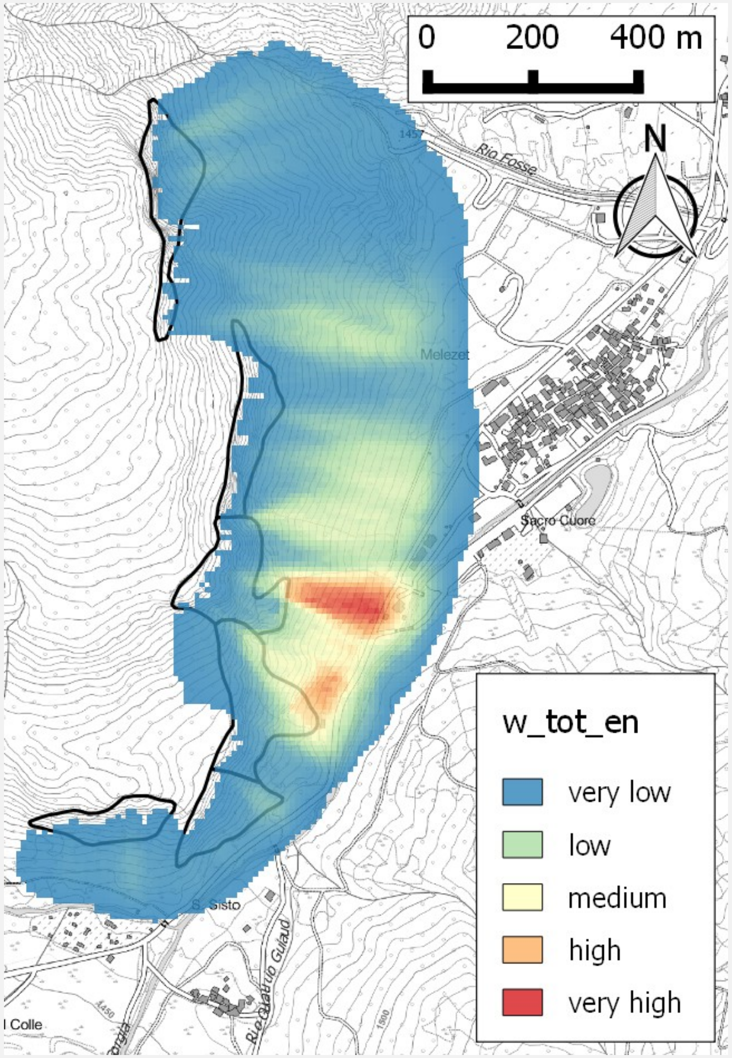


(Raster layer of the maximum energy in every cell, within runout area. [J])

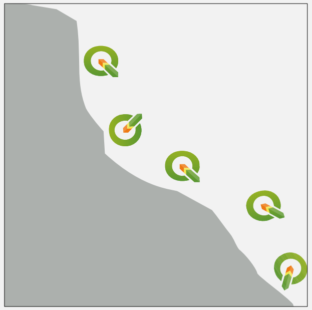
CASE HISTORY



(Raster layer of the maximum weighted energy in each cell within runout area. [J])



(Raster layer of the total weighted energy in each cell within runout area. [J])



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