A free tool integrating GIS features and workflows to evaluate sediment connectivity in alpine catchments

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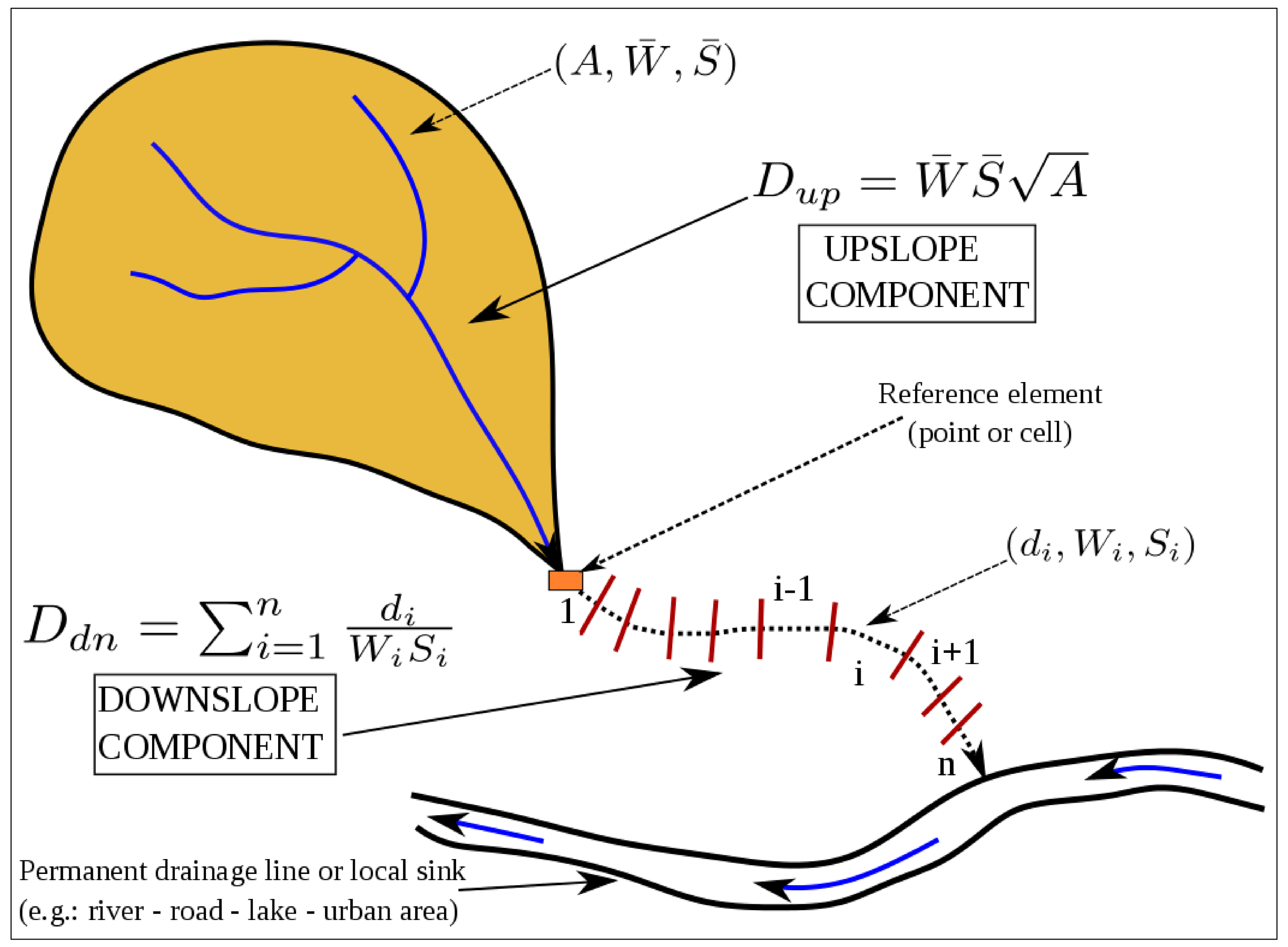
Introduction

Sediment connectivity plays a significant role in geomorphic systems since it reflects the potential of sediment, deriving from soil erosion and remobilization of storages, to be transferred within or between landscape compartments. Understanding sediment movement and delivery to given areas of interest or sinks (e.g. channel network, urbanized area, catchment outlet) is an important issue for efficient management strategies. Thanks to the availability of high-resolution Digital Terrain Models (DTMs) different methods for mapping connectivity have been developed (e.g. Heckmann and Schwanghart, 2013), usually building workflows using GIS software or basing on programming/scripting languages. In this work, a **free**, **open source** and **stand-alone** model of sediment connectivity developed following the approach of Borselli et al. (2008) with ad hoc refinements devised to adapt the model to mountain catchments using high-resolution DTMs (Cavalli et al., 2013), is presented with its main features and a test application.

Sediment connectivity model



The connectivity index *IC* is aimed at evaluating the potential connection between hillslopes and features acting as targets (e.g. catchment outlet, roads) or storage areas (sinks, retention basin) for transported sediment. *IC* consists of two components:

- **Upslope component** D_{up}: is the potential for downward routing due to upslope catchment area, mean slope and a weighting factor

$$D_{up} = \bar{W}\bar{S}\sqrt{A}$$

where $\bar{W}$ and $\bar{S}$ are the average weighting factor and slope gradient of the upslope area *A*.

The proposed default weighting factor is based on surface roughness computation (Cavalli et al., 2013). The surface roughness is computed as the standard deviation of residual topography

$$RI = \sqrt{\frac{\sum_{i=1}^{s^2}(x_i - \bar{x})^2}{s^2}}$$

where *s* is the moving window size, x_i is the residual topography at a specific location and $\bar{x}$ is the averaged value within the moving window. The Weighting factor is then computed

$$W = 1 - \left(\frac{RI}{RI_{max} + 0.001}\right)$$

RI_{max} is increased to avoid division by zero in the following elaborations.

- **Downslope component** D_{dn}: is the sinking potential due to the path length, impedance factor and slope along the downslope path

$$D_{dn} = \sum_{i=1}^{n} \frac{d_i}{W_i S_i}$$

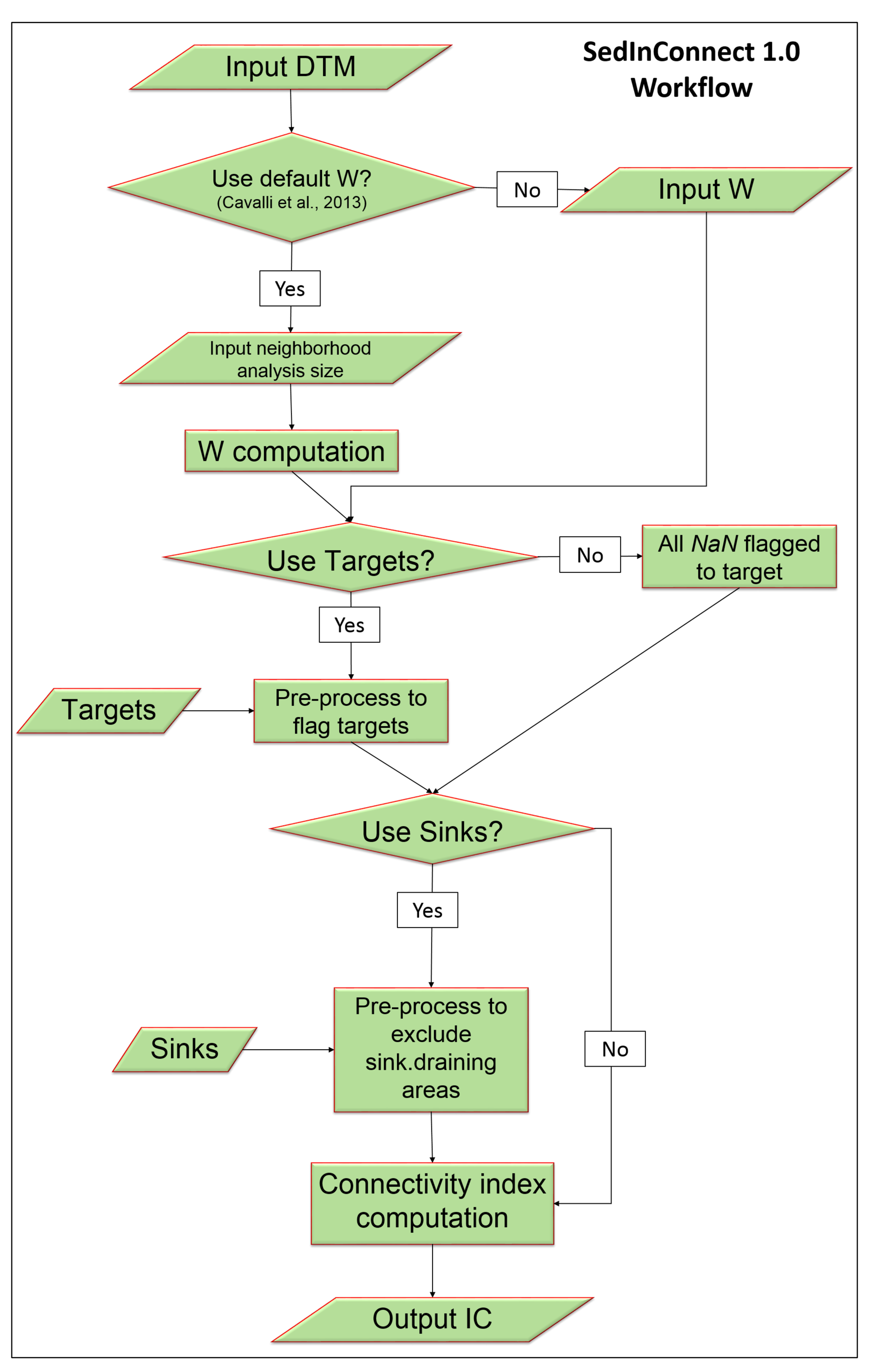
where, for the i^{th} cell, d_i is the length of the flow path, W_i and S_i are the weighting factor and the slope gradient.

IC is defined as:

$$IC = \log_{10} \frac{D_{up}}{D_{dn}}$$

SedInConnect workflow

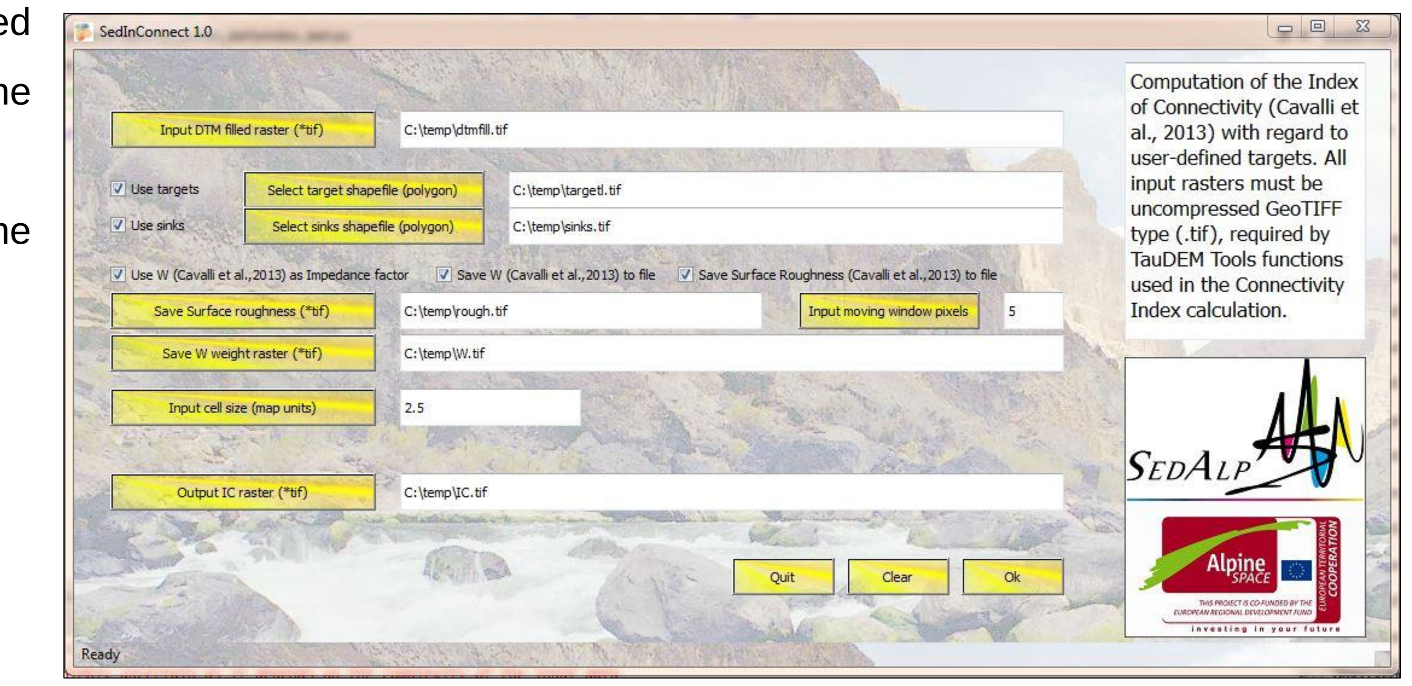
The **SedInConnect 1.0 implementation** follows the approach proposed by Cavalli et al. (2013) with some further refinements. The possibility to use the the surface roughness as the default weighting factor is included, furthermore a novel feature is represented by the optional use of sinks. By using sinks (lakes, open check dams, karstic areas) the model decouples sink-draining areas from the Connectivity index calculation.

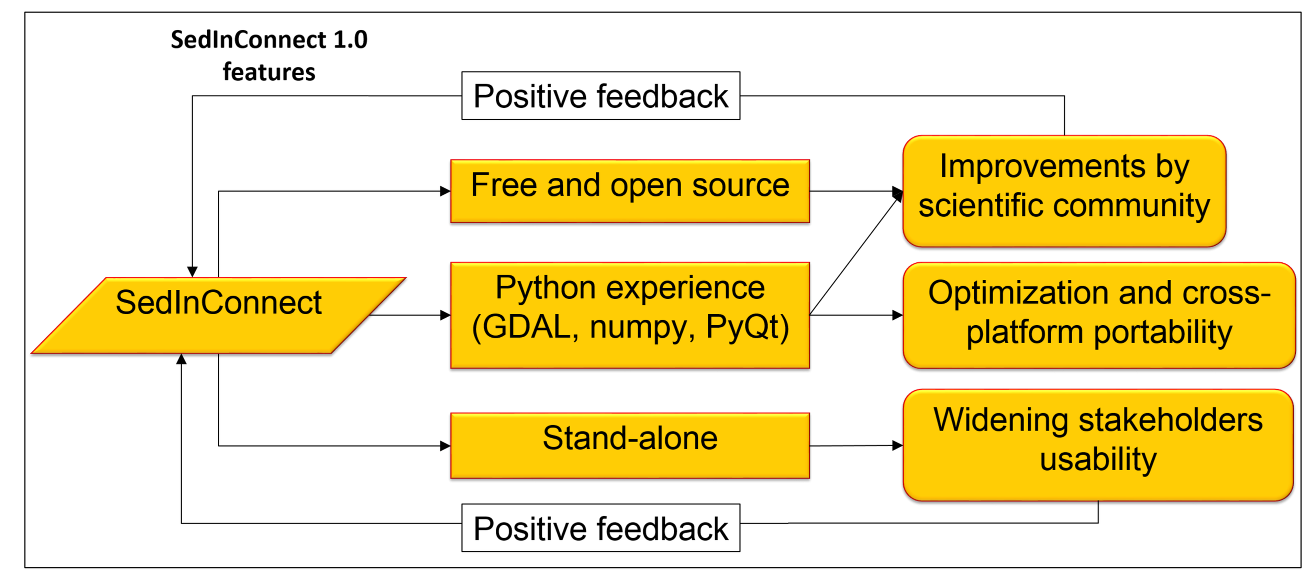


Features and Interface

The tool presents an intuitive interface in which all the mentioned options can be selected. The development of the tool benefits from the use of several features:

- Being **free** and **open-source** it can be directly improved by the scientific community
- Using **Python-based** libraries brings several advantages:
  1. *Easy portability across platforms*
  2. *Optimization of array operations*
  3. *Simple GUI development*
  4. *Ready to use routines for Geospatial Data management*



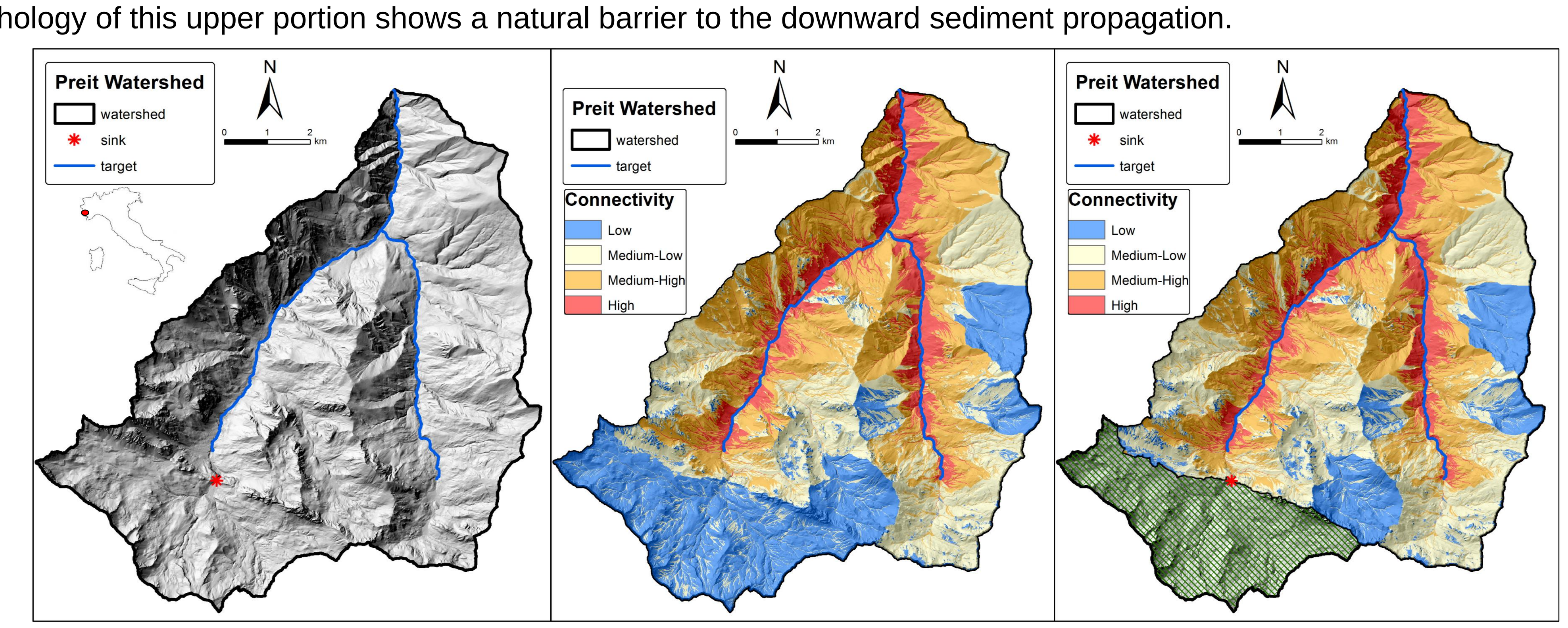


- Being **stand-alone**, the tool tries to open the access to the Connectivity modeling as much as possible. This way it can be used by several stakeholders, including local authorities directly involved in the integrated management of natural resources. Furthermore the tool is efficient from a computational point of view making a wide use of **TauDEM Tools** routines (Tarboton, 1997) and avoiding the creation of all the intermediate files, typical of the most common GIS software model builders.

Application

The model has been applied to a sample catchment in the Northwestern Italian Alps. The target feature along with the novel sink feature have been tested. The Connectivity index was calculated considering as target the main channel network. The upper part of the basin is characterized by an evident structural control. The morphology of this upper portion shows a natural barrier to the downward sediment propagation.

The same area has furthermore a karstic behavior, and the whole zone is draining to a small natural lake acting as a sink for the upstream coming sediment. It has been decided to correctly decouple this area from the Connectivity analysis since the upcoming sediment is not propagating until the selected target feature.



Remarks

SedInConnect starts as an open and useful tool in order to evaluate sediment connectivity dynamic in mountain catchments. The choice of going for a **free, open, and stand-alone** software is motivated by the need of improving direct participation to the model improvement. The overall goal of this tool is indeed supporting the analysis of sediment connectivity, facing the challenge of **spreading**, as much as possible, **the users community** among scientists and stakeholders. This aspect is crucial, as future improvement of **this tool will benefit of feedbacks** from users in order to improve the quantitative assessment of sediment connectivity as a major input information for the optimal management of mountain areas.

References

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