Automatic Delineation of Geo-Morphological Slope Units

M. Alvioli, I. Marchesini, F. Fiorucci

M. Rossi, P. Reichenbach, F. Guzzetti

Research Institute for Geo-Hydrological Hazards

of

National Research Council

(Perugia, Italy)

PROTEZIONE CIVILE

Regione Umbria

CONTENTS

1. Motivation

- Selection of appropriate ***mapping units*** is a common requirement of many models in natural hazards assessment and mitigation, slope stability, erosion problems, land use planning and any statistical analysis

  F. Guzzetti et al., Geomorphology 31 (1999) 181-216

- Going *beyond a pixel-based description* is the zero-requirement, due to loss of any terrain-related information and neighborhood relations when using grid cells

- Many criteria have been proposed to define (geo-morphological) *terrain units*, (geometrical) *landforms*, *segmentation/classification* of (satellite) images and others, in relation to the *specific problem*

- We focus on ***landslides*** problems and we implement ***slope units*** as a *partition of slopes between **drainage** and **divide** lines* as in

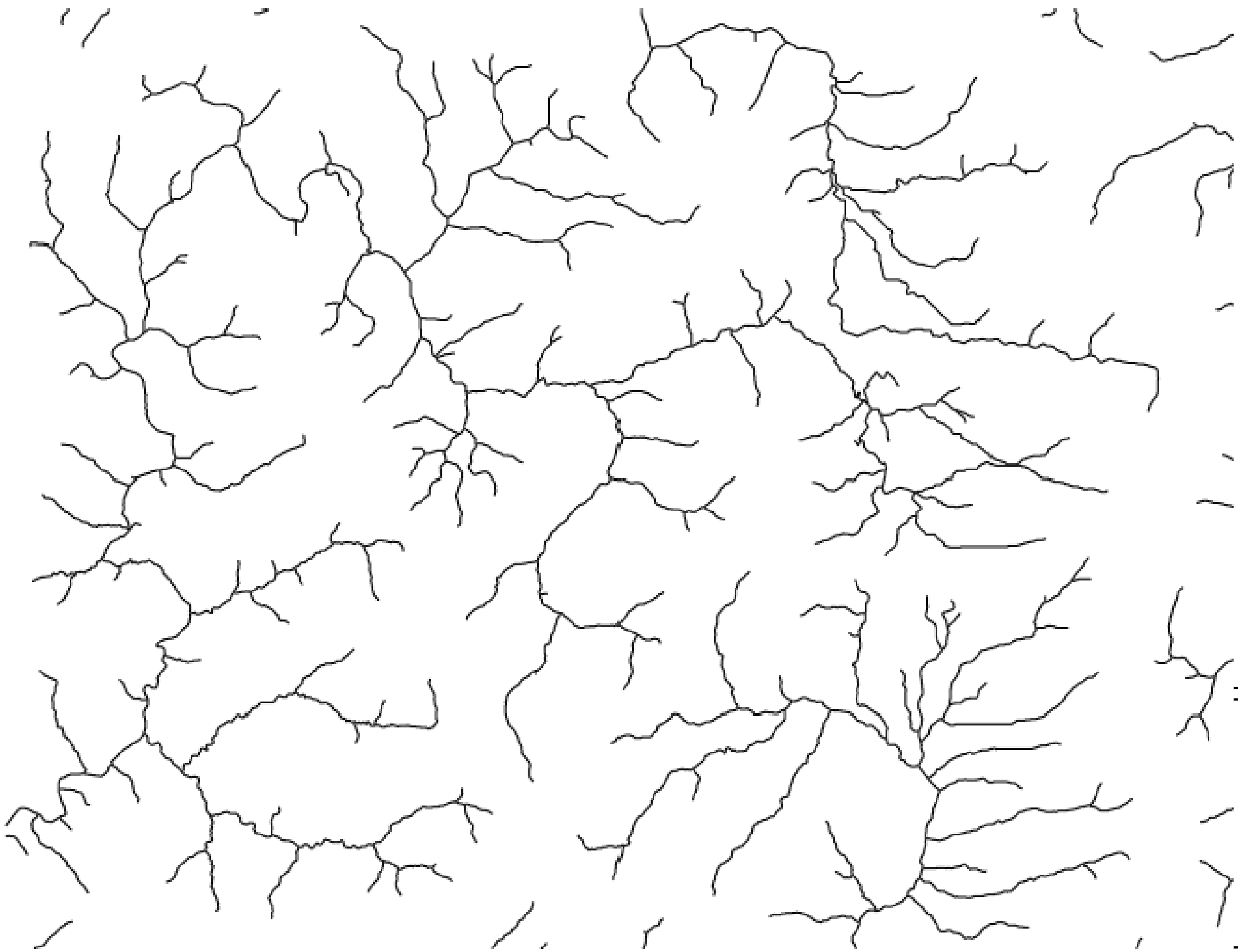
  A. Carrara et al., Earth Proc. Surf. Land. 16 (1991) 427

- An automatic delineation of SUs reduces *subjectivity* and researchers *time*

2.1 Definition of Slope Unit & computational strategy

- We refer to ***Slope Units*** as portions of land slope with the general requirement of *maximizing homogeneity* within each unit and *heterogeneity between different units*, in relation to the problem one is looking at
- For our class of problems, we try and maximize the *aspect* homogeneity
- Automatic classification with some *threshold* is highly unsatisfactory and presents an intrinsic *scale problem*; see *e.g.*
  L. Drăguț et al., Geomorphology, 81 (2006) 330-334
- Bottom-up approach *vs.* top-down approach:
  - *bottom-up* starts from a fine partition of the slopes, then group together similar units. Tipically based on image (aspect) classification
  - *top-down* based on pure hydrologic partition into half-basins, with smaller contributing area providing finer partition
- We adopt an *iterative, hybrid approach*, to maximize performance, and *select the scale of the result as a function of* ***typical landslide size***

2.2 Drainage Network vs. Contributing Area Threshold



WATERSHED THRESHOLD: 5000 CELLS

- Drainage network generated with a given threshold of contributing area can be *arbitrarily dense*
- Used to generate a hydrologically-consistent partition of the area into ***half-basins***

⇒ Size of Slope Units varies according to the purpose they are generated for

⇒ Need ***different*** *contributing thresholds* in different regions of the study area

2.3 Half-Basins Size vs. Contributing Area Threshold

WATERSHED THRESHOLD: 5000 CELLS

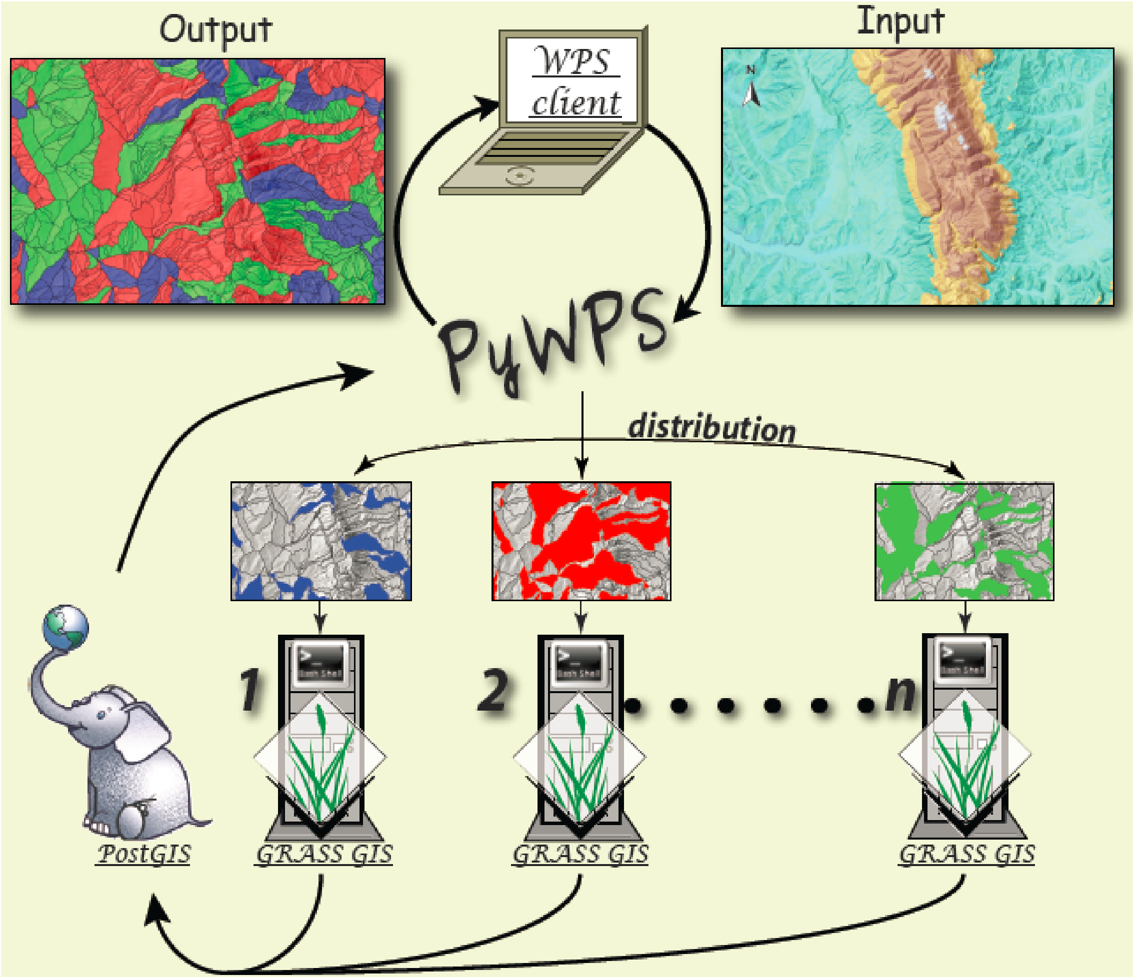
- The half-basins associated to the drainage network become *arbitrarily small* with inreasing accumulation threshold
- Need to ***cluster*** "*similar*" half-basins and keep apart "*different*" ones

⇒ We *stop* the partitioning process on those regions where SU *area is small enough* and/or SU *aspect is homogeneous enough* (input parameters)

3.1 Our algorithm implemented as WPS services

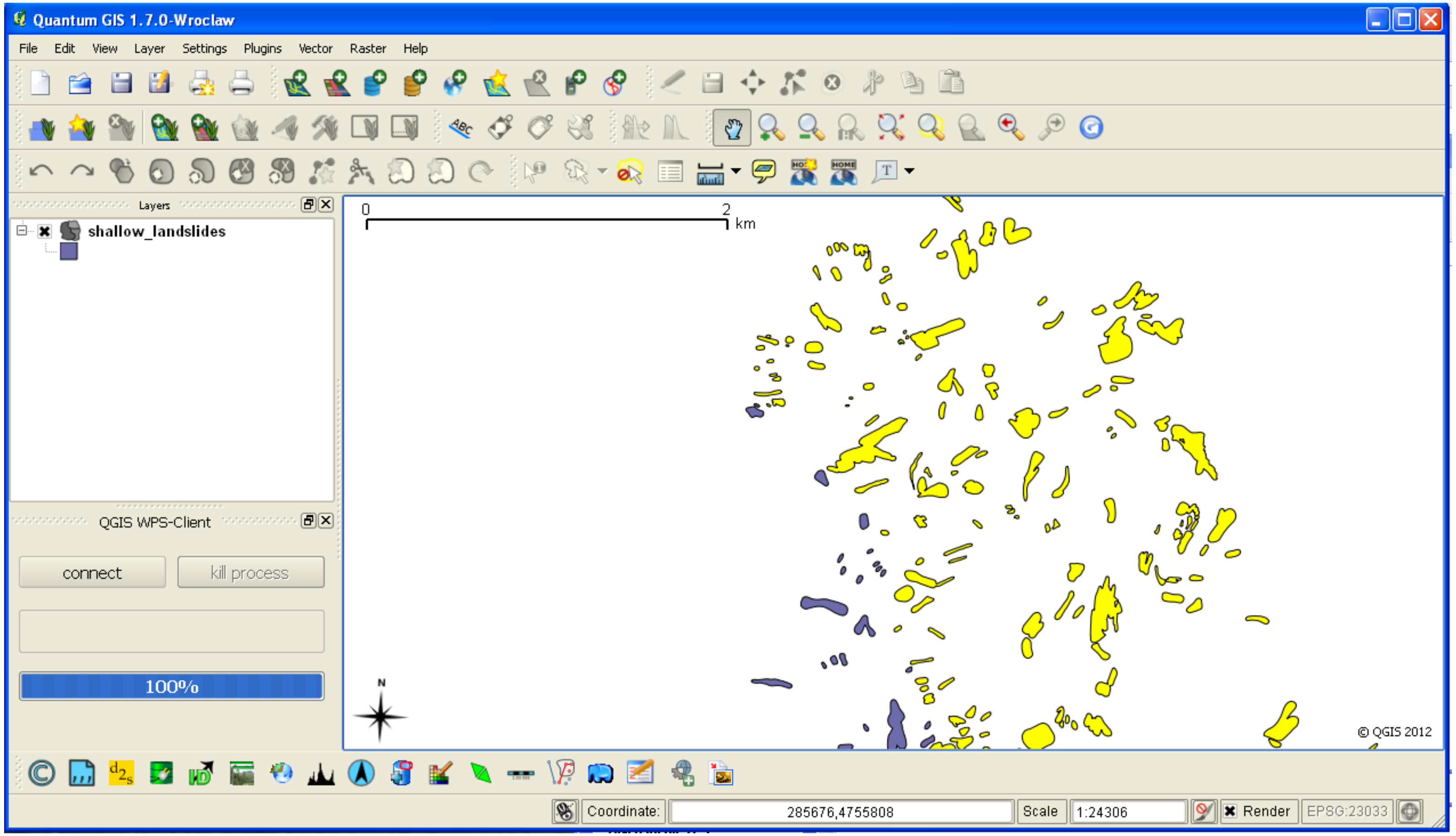
Slope units delineation

- input: DTM raster map, model parameters, plains vector layer
- *processed in parallel* with multiple instances of GRASS GIS
- the output is a vector layer with *slope units*
- use a WPS client (*i.e.*, QGIS) and connect to:



http://alpha.irpi.cnr.it/cgi-bin/pywps.cgi

3.2 The Web Processing Services interface (in QGIS)



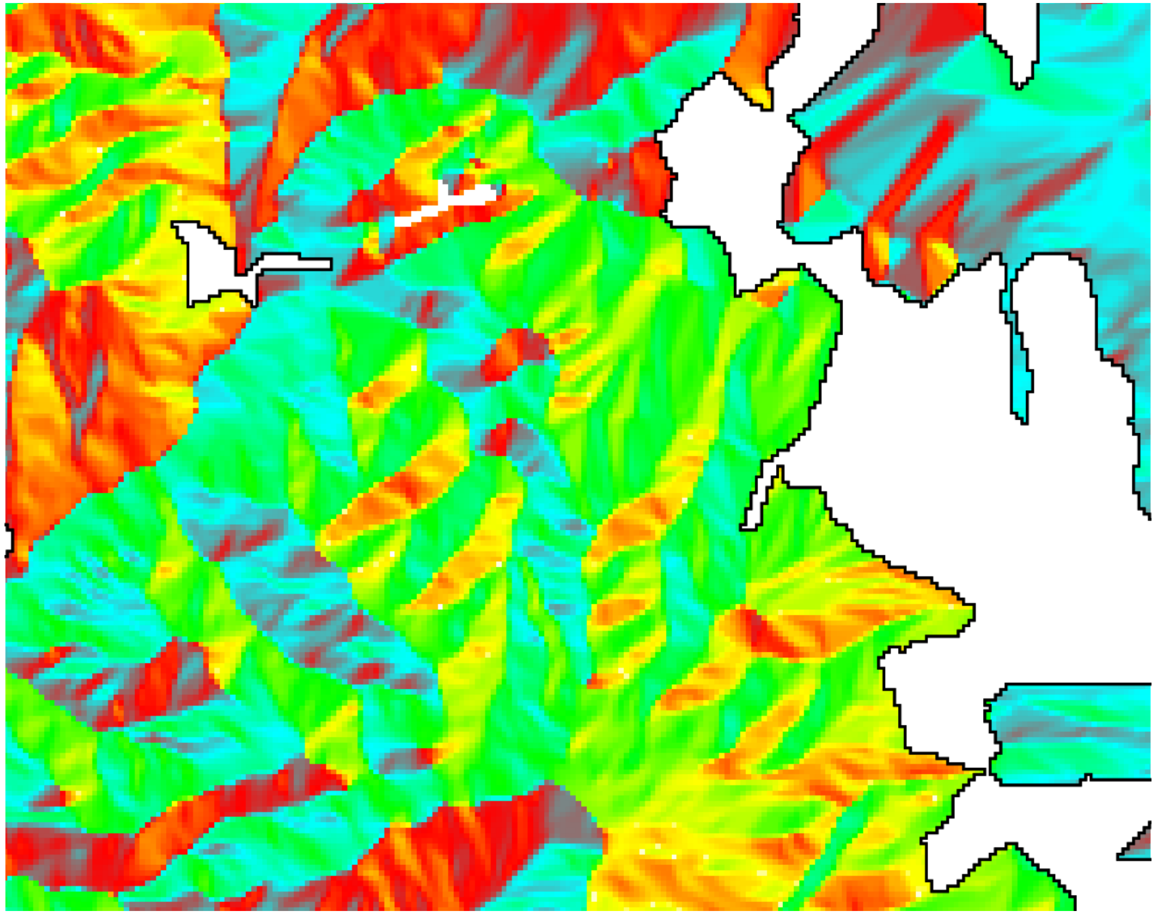
The interface to upload *maps*, specify *parameters* and *run the service*

http://alpha.irpi.cnr.it/cgi-bin/pywps.cgi

4.1 Full description of our iterative process

- We adopt an iterative, hybryd approach, to maximize performance
- At each iteration, with a given value of contributing area threshold, we *flag as Slope Units* those half-basins with:
  - standard deviation of ***aspect*** *under a given value*
  - surface ***area*** *under a given value*
- We *decrease the contributing area threshold* and generate new streams for all the *remaining* of the study area
- Multiple iterations are performed until no area is left unclassified
- A further iteration is performed to *aggregate small areas* on the basis of aspect homogeneity, with small violations of the drainage/divide partition
- Optionally delete residual small areas, smooth Slope Units boundaries & unwanted artifacts

4.2 Example of a few iterations to obtain the final result

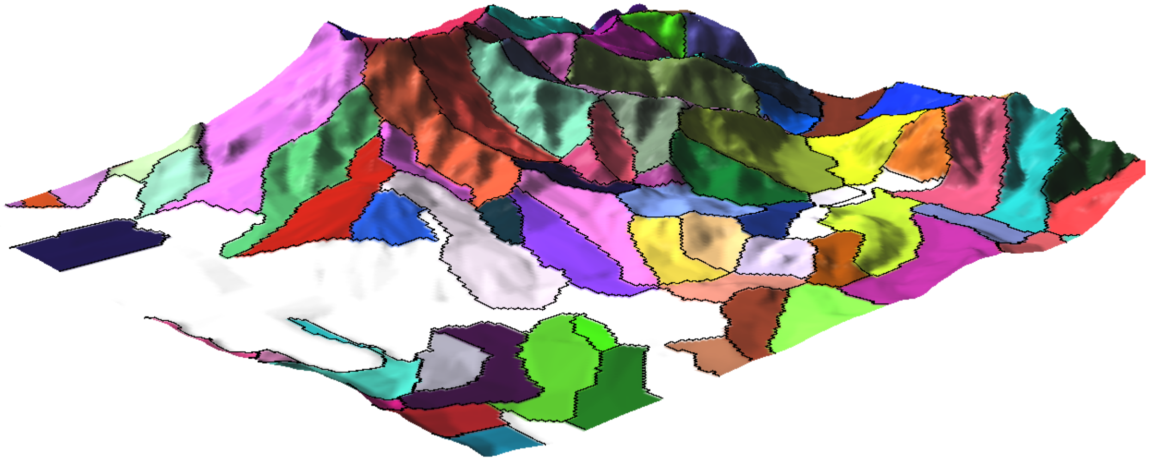


- Our iterative process can be supplemented with additional aggregation/rejection of aggregation criteria for production of custom Slope Units
- An additional layer can be provided whose features are used to tune our algorithm parameters (*e.g. landslides layer*)

- We can implement *additional* criteria for the definition of Slope Units
- We incourage users to use our services and contact us to provide feedback

http://alpha.irpi.cnr.it/cgi-bin/pywps.cgi

4.3 Customization of Slope Units: more criteria needed

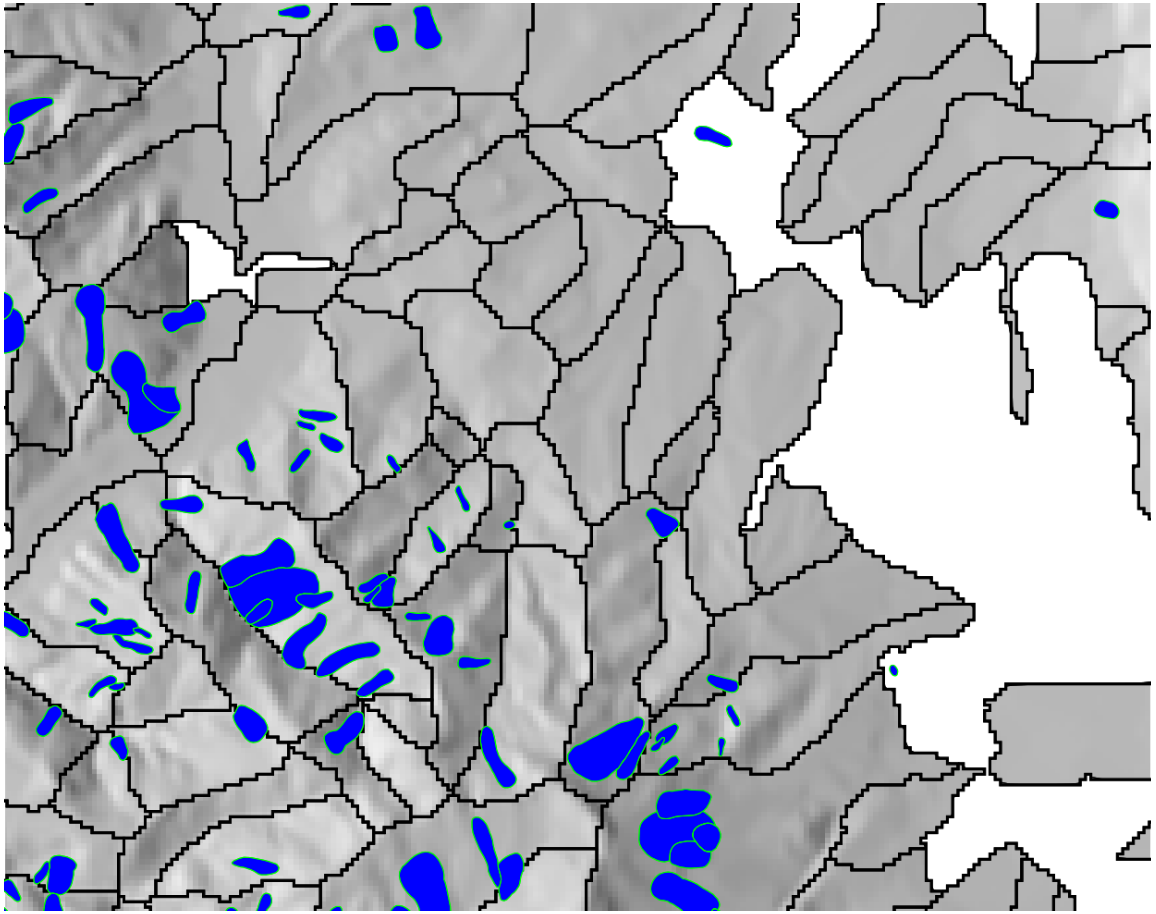


- Our iterative process can be supplemented with additional aggregation/rejection of aggregation criteria for production of custom Slope Units
- An additional layer can be provided whose features are used to tune our algorithm parameters (*e.g. landslides layer*)

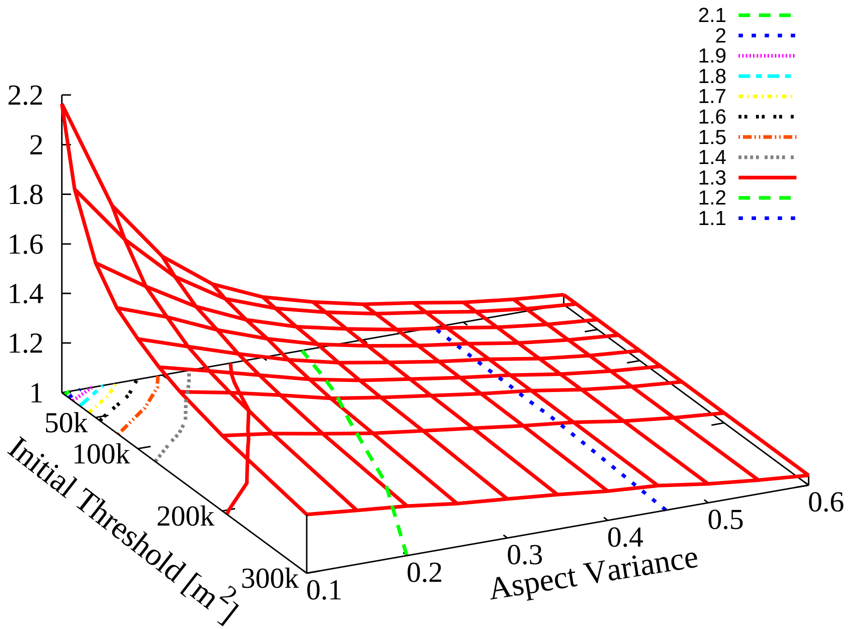
- We can implement *additional* criteria for the definition of Slope Units
- We incourage users to use our services and contact us to provide feedback

`http://alpha.irpi.cnr.it/cgi-bin/pywps.cgi`

4.4 Constraining model parameters with landslide inventories



- We infer the model parameters from statistical properties of an inventory of landslides
- We test the performance of our algorithm by the **ratio** of number of slides cut by SUs boundaries to the initial number:



- We also minimize the landslide area cut by the SUs boundaries
- Our strategy *greatly reduces the scale dependence* of the problem

5. Conclusions

- We have implemented an iterative algorithm for efficient, automatic delineation of Slope Units
- Our algorithm maximizes aspect homogeneity in each Slope Unit, keeping the consistency with hydrological properties of the input DTM
- We have implemented a number of **W**eb **P**rocessing **S**ervices

⟶ *publicly available* using a WPS client (*i.e. QGIS*)

⟶ the services exploit *parallel processing* on CNR-IRPI (Perugia, Italy) computing infrastructure

- We encourage users to connect to our services and provide us with feedback and requests
- My ***final message***: use our WP Services available at

`http://alpha.irpi.cnr.it/cgi-bin/pywps.cgi`