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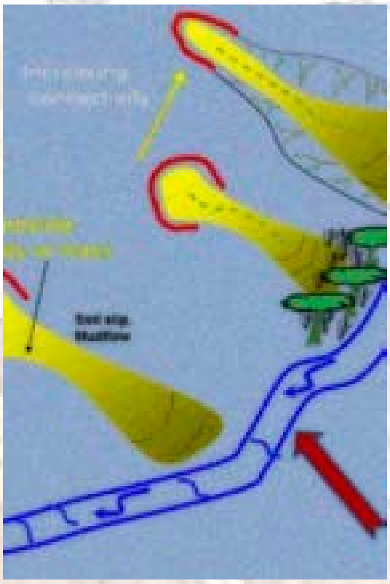

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PESERA L model: an addendum to PESERA model for Sediment Yield due to Shallow mass movement in a watershed

By
Lorenzo Borselli[1], Pilar Salvador Sanchis[1],
Devis Bartolini[1] Paola Cassi, Piernicola Lollino' .

[1]Consiglio Nazionale delle Ricerche, Istituto di Ricerca per la Protezione idrogeologica, - CNR-IRPI
Via madonna del Piano 10, 50019 Sesto Fiorentino (Florence), Italy. www.irpi.fi.cnr.it, borselli@irpi.fi.cnr.it

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This report contributes to the following deliverables of the DESIRE project:
5.2.1. Improved process descriptions integrated within the PESERA model in order to be able to evaluate the effects of potential prevention and remediation measures;
5.3.1. Model outputs for each hotspot site to identify the likely environmental, environmental and social effects of proposed remediation strategies

Introduction: Shallow mass movement and Sediment Yield in a watershed

Local mass movements of soil result from local severe degradation processes are usually associated with other forms of erosion such as rills, pipes and gullies. In agriculture, mass movements inhibit farm operations by loss of accessibility, exposure of infertile subsoil and unprotected soil surface layers to splash and rill erosion, and net downslope movement of the soil mass. Gravity is the principal force producing slides, slips, slumps, flows and landslides. At a particular water content soil becomes unstable and can slide downslope. Landslides and mass movements are usually classified by type and velocity of movement (Varnes, 1978). Rapid movements of soil mass over a distinct sliding surface are termed "landslides". Generally mass movement occurs when the weight (shear stress) of the surface material on the slope exceeds the retaining ability (shear strength) of the material. Risk of mass movement is increased by erosion or excavation undermining the foot of a slope, loss of stabilizing roots through removal of vegetation and increase in pore water pressure within the soil profile. Increased pore water pressure or greater water absorption may weaken intergranular bonds, reducing internal friction, therefore lessening the cohesive strength of the soil and, ultimately, slope stability. Usually slope stability is determined quantitatively by the ratio between available shear strength of soil mass and imposed shear stress computed along the assumed sliding surface:

$$F_s = \frac{T}{S} \qquad [1]$$

where Fs is the stability factor and depends on the shape of the sliding surface and on the type of movement, T is the shear strength (the sum of resisting forces), S is the shear stress (the sum of driving forces). Values of Fs < 1, Fs > 1 and Fs = 1 correspond respectively to unstable, stable and metastable slopes. Considering the spatial and temporal variability of soil properties, values of Fs > 1.2 are considered satisfactory for stable conditions in a conservative analysis. For shallow mass movements, the infinite slope approach assuming planar movements (Figure 1) is commonly used.

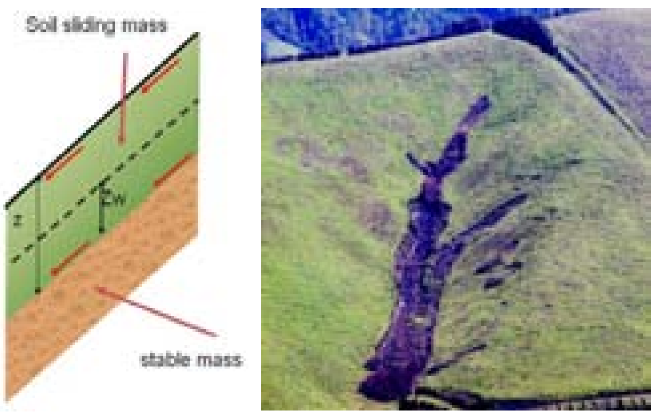


figure 1: shallow mass movements, the infinite slope:
modelling approach assuming planar movements is commonly used.

The stability factor Fs may be evaluated from eq. 2 and 3 :

$$F_s = \frac{\frac{c'}{\gamma Z}(cos^2\beta - r_u) \ \tan\varphi'}{\sin\beta\cos\beta} \quad [2]$$

$$r_u = \frac{9.81 Z_w}{\gamma Z} \quad [3]$$

Where: Z is the depth of the soil layer or the slip surface in the topsoil used to evaluate stability, Z_w is the height of the water table above the slip surface , ß is the local slope angle, ϕ' is the angle of soil internal friction, c' is the internal cohesion of the soil including apparent cohesion induced by roots until rooting depth , γ is the unit weights of soil, r_u is coefficient of interstitial pressure that gives also the level of saturation of soil mass.

Eq. 2 applies to planar sliding of the soil mass where sliding surface and seepage flow are approximately parallel to the land surface. Such conditions only occur in some instances, whereas the infinite slope criterion is used for evaluating stability over large areas or watersheds. Some computer models use the infinite slope method under probabilistic and deterministic approaches (LISA) (Hammond et al., 1992[1]).

The general form of eq. 2 is a fully deterministic model. Many factors influence the local stability condition and the occurrence of diffuse shallow landslides in a wider areas.

Local factors influence are the additional resistance of vegetations and roots until rooting depth, the presence of cracking soil and the potential effect of preferential flow and rapid saturation of deeper horizons. The climate factor and rainfall pattern that produce seasonal saturation of unstable mass determining the collapse wherein a given triggers are overcomes.

At wider scale the spatial variability of soil and surface conditions play a important role. Many researchers indicate that diffuse shallow landslides have a relevant importance contributing to sediments yield in a watershed (De Vente and Poesen (2005)[2]). Maquarie and Malet, 2006[3]).

Nevertheless this problems in the integration of the shallow landslides contribution to SY with the classical water erosion processes. The classic water erosion processes aren't enough integrated with mass movement because of the large differences in mobility of sediments. The only exception are the rapid mass movements and all gravitational processes that are characterised by large runout distance and mobility: debris flow , lahars, flowslides and mudslides. The shallow landslides are mass movement that in some circumstances can transform easily in debris flow, flowslides or mudflow. The proximities of the landslide to a permanent drainage network can contribute to an easier transfer to the watershed outlet of soil mass mobilised by landslides. The transfer of the soil mass to the outlet depends mainly from: a)the

1 **Hammond, Carol; Hall, David; Miller, Stanley; Swetik, Paul.** 1992. *Level I Stability Analysis (LISA) documentation for version 2.0*. Gen. Tech. Rep. INT-285. Ogden, UT: U.S. Department of Agriculture, Forest Service, Intermountain Research Station. 190 p.

2 De Vente, J., Poesen, J., 2005. Predicting soil erosion and sediment yield at the basin scale: scale issues and semi-quantitative models. Earth-Science Reviews 71, 95–125.

3 Maquaire O. , malet J.P. 206). Shallow Landsliding. Chap. 2.9 . In "SOIL EROSIONE IN EUROPE" (J. Boardman and J. Poesen– editors). John Willey & Sons Ltd, West Sussex. England. pp. 583-597

intrinsic degree of the mobility of the processes b) the distance of the point of origin to the nearest channel at the end of hillslope and c)the easiness to complete this path.

The points a , b, and c involve two basic concepts emerging in the territorial appraisal in sediment mobility: the connectivity approach.

The potential landslide volume for pixel can be transformed into potential erosion using a modified connectivity index, specific for landslides, and developed from the ones defined by Borselli et al. (2008)[4]. The new map of landslide active process of Rendina basin will be used to test the model making a generalized back analysis to establish the range of operability. After this we can propose it, within the PESERA framework, together the Montecarlo – stochastic implementation of the infinite slope model.

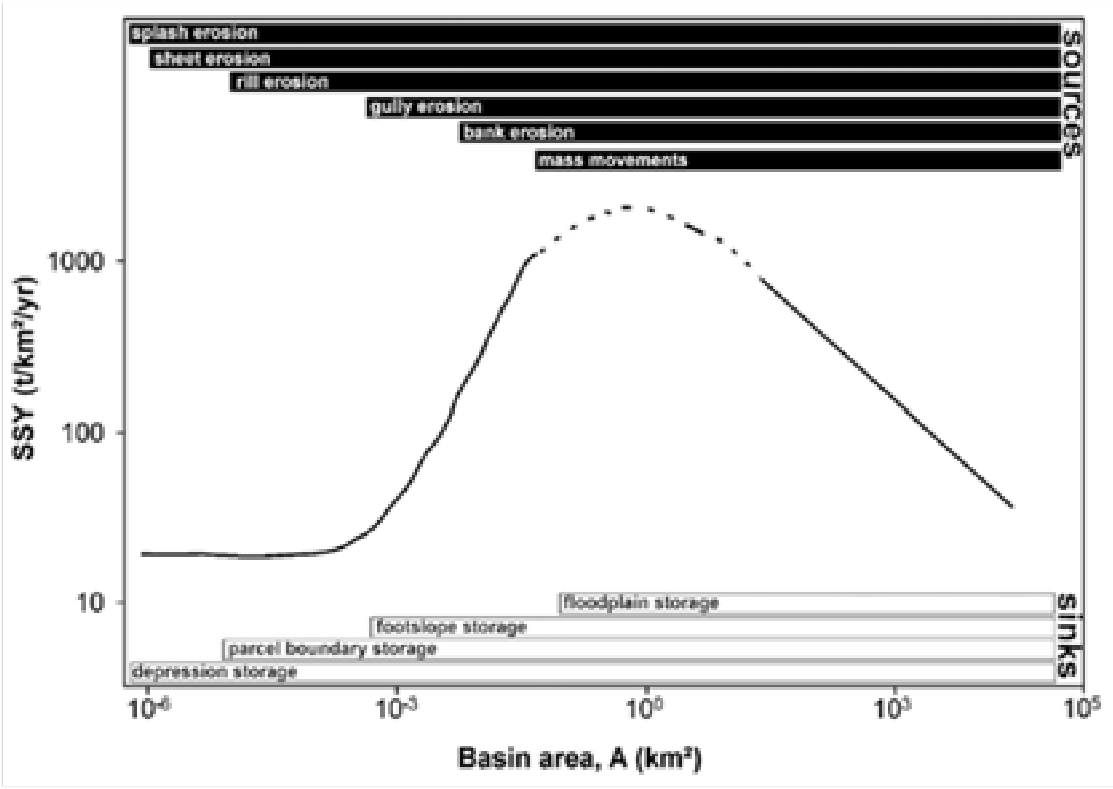


Figure 2: Conceptual model of specific sediment yield (SSY) at various scale and contributing sources and sinks (De Vente and Poesen, 2005[5])

PESERA Constraints and model integration strategy

The integration in PESERA of a landslide component puts some problems. Firstly the scale of application of PESERA. The final scale of resolution of PESERA (90-100 m), produce the loss of most of the detailed information needed to describe deterministically some input parameters that are commonly used in the models for slope stability, that use the Limit Equilibrium Infinite Slope Models (LEISM). An example of this problem is the slope gradient that at coarse scale of resolution loss their significance for local stability calculation. The second problem is the stochastic approach of PESERA model, that has been developed to account of the generalization required of the coarse scale application. Following these main constraints we develop the first version prototype **PESERA-L component**.

4 BORSELLI L., P. CASSI, D. TORRI. 2008. Prolegomena to Sediment and flows connectivity in the landscape: a GIS and field numerical assessment. CATENA 75(3): 268-277.

5 De Vente, J., Poesen, J., 2005. Predicting soil erosion and sediment yield at the basin scale: scale issues and semi-quantitative models. Earth-Science Reviews 71, 95–125.

PESERA-L model for landslides components :Probabilistic infinite slope model for slope stability

A stochastic implementation Limit equilibrium model approach has been developed and applied with success from many authors for application at shallow landslide processes (Hammond et al. 1992, Capra et al. 2003[6]) . Following a full stochastic approach each parameters that appears in the eq. 2 and 3 become a random variable distributed following a predefined statistical continue distribution. Usually the slope angle is assumed deterministic because this information can be obtained at fine scale starting from a fine resolution DEM (5X5 to 30X30). The application inside the PESERA framework required a generalisation because the slope gradient that is contained in each element at coarse scale raster representation (e.g. 100x100 m pixel) cannot be used directly . The possible solution it is assign also to slope gradient, used in the FS computation in eq. 2, a stochastic representation like all other geomechanical and hydrological parameters. In this way the all statistical information content is preserved until the final result and calculations.

The application based on stochastic form of the equation 2 and 3 will produce, with Bayesian or Montecarlo algorithms, a final distribution of Fs, or the stability factor. The percentage of non excedance of the Fs=1 will give the information of the overall degree of stability and thus on the probability of unstable condition.

The slope spectrum sub model and integration

The slope spectrum approach developed by Wolinsky and Pratson (2005)[7] and Tang et al. (2008)[8] has been used to define statistically the slope gradient in the PESERA-L. The PESERA classic topographic indexes are not suitable to define correctly the slope gradient information for this specific use. For this reason we adopted the beta distribution for modelling the continuous slope spectrum(fig. 3). The beta distribution is defined by the eq. 4 and 5

6 CAPRA L. , J. LUGO-HUBP , L. BORSELLI. (2003). "Mass Movements In Tropical Volcanic Terrains: The Case Of Teziutlán (México)". Engineering Geology, vol. 69 (3-4):359-379

7 Wolinsky and Pratson (2005). Constraints on landscape evolution from slope histograms. Geology 2005;33;477-480 doi:10.1130/G21296.1

8 TANG, FaYuan, LIU , LONG Yi & YANG (2008). Research on the slope spectrum of the Loess Plateau. *Sci China Ser E-Tech Sci* || vol. 51 | Supp. I | **175-185**

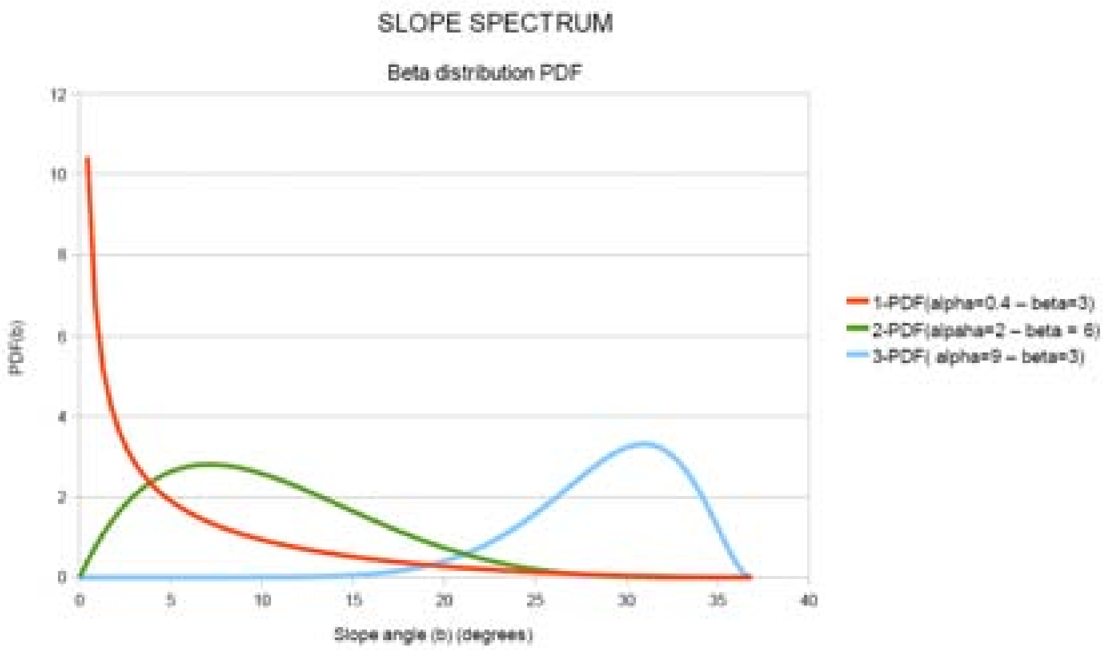


Figure 3: slope spectrum related to 3 differents land unit

$$f(x)=\begin{cases}\dfrac{x^{\alpha-1}(1-x)^{\beta-1}}{B(\alpha,\beta)} & 0\le x\le 1\\ 0 & \text{otherwise}\end{cases} \qquad [4]$$

$$F(x)=\begin{cases}\dfrac{B_x(\alpha,\beta)}{B(\alpha,\beta)} & 0\le x\le 1\\ 0 & \text{otherwise}\end{cases} \qquad [5]$$

Where eq. 4 defines is the probability density function (PDF) the Cumulative frequency distribution (CDF) of a beta distribute random variable.

In the equation 4 and 5 $B(\alpha,\beta)$, $B_x(\alpha,\beta)$ are respectively the Beta Function and the Incomplete Beta Function usually tabulated or available in common numerical calculus libraries.

α,β are resepcitively the shape and scale parameters (fig.3) that can vary in the range $[0,+\infty]$ and can represent a large variety of shapes. The beta distribution can be further generalised because the random variable can be defined, rescaling the standard beta distribution interval [0,1] as $x\in[x_{MIN},x_{MAX}]$.

In figure 4 is shown the slope spectrum associated to the LUS characterized by land use code 211 (cereal crops) and soil unit 14.2 in the Rendina watershed (n. 116450 slope gradient sampled pixels at 20 meters resolution).

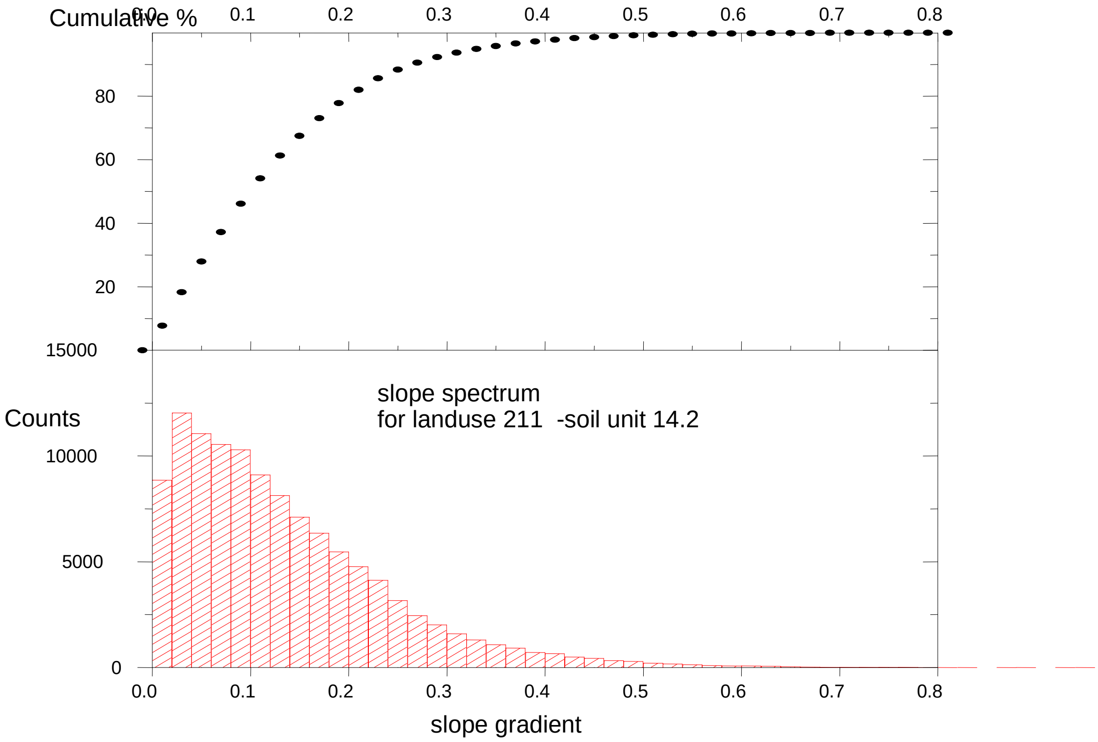
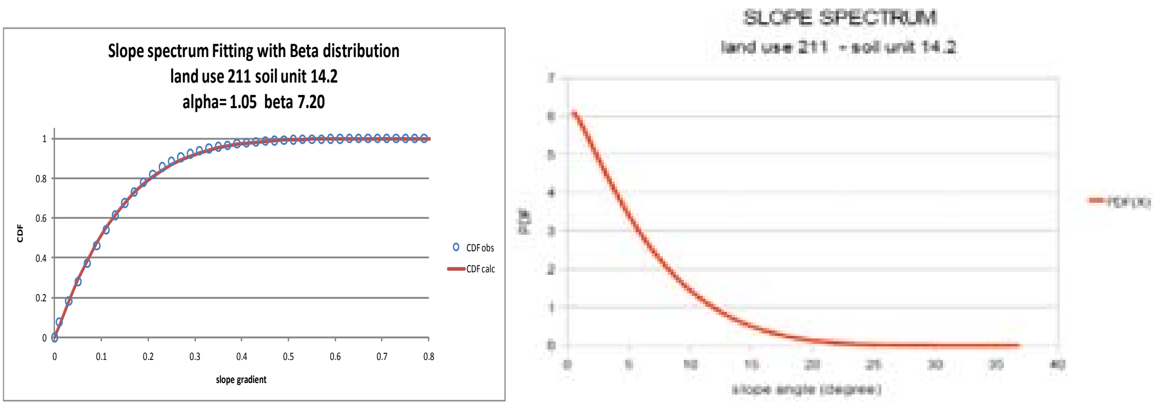


Figure 4: slope spectrum and Cumulative frequency distribution (CDF) associated to the LUS characterized by land use code 211 (cereal crops) and soil unit 14.2 in the Rendina watershed (n. 116450 slope gradient sampled pixels, 20 meters resolution)

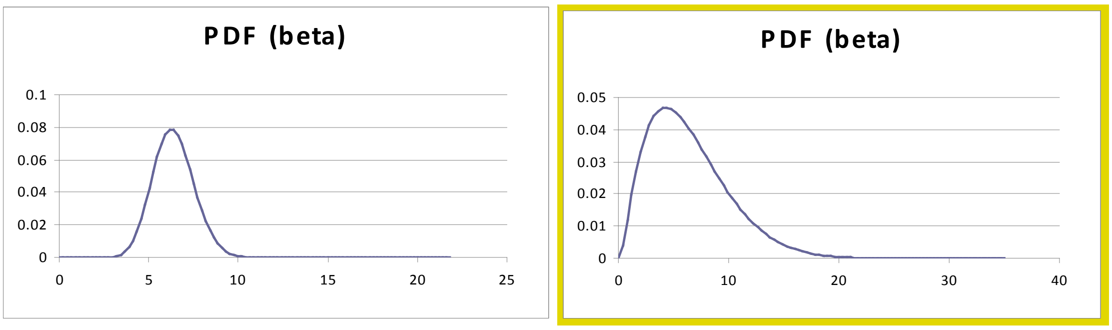
The CDF in figure 4 can be easily fitted in order to obtain the α, β parameters. Figure 5 shows the fitting on the CDF and the PDF vs. the slope angle for the same LUS



• (b)

Figure 5 a,b

Figure 6 a,b show the slope spectrum of two different LUS characterized by the same land use 211 (cereal crops)and different soil unit, respectively 6.3 and 9.3. In the table 3 the statistical parameters calculated for some LUS with land use 211 (cereal crops).



a) b)

Fig. 6: slope spectrum of two different LUS characterized by the same land use 211 (cereal crops)and different soil unit, respectively 6.3 (a) and 9.3 (b).

Soil	6_2	6_3	6_4	7_3	7_5	9_1	9_2	9_3
Max	0.403	0.808	0.752	0.791	0.279	0.401	0.984	0.692
Min	0.003	0	0	0	0.002	0.099	0	0
media	0.1912839	0.211361	0.2373963	0.1595235	0.087165	0.2399394	0.1596267	0.1157366
mediana	0.201	0.213	0.236	0.155	0.069	0.231	0.137	0.112
1 quart	0.1225	0.139	0.175	0.113	0.05	0.186	0.081	0.068
3 quart	0.239	0.279	0.296	0.199	0.124	0.309	0.202	0.155
Skewness	0.1161863	0.2513274	0.2845791	0.7367156	0.8548086	0.088239	1.8120818	1.0674365
Kurtosis	-0.3089752	0.3492475	0.5545535	1.8381401	-0.1572921	-0.7457649	4.8425078	4.1549007
Dev.st	0.0989641	0.0990916	0.098731	0.0734925	0.0513878	0.0774213	0.1168277	0.0658305
Num. Punti	155	14060	25319	159441	2369	33	30174	15319
mean (normalized)	0.47071	0.261585	0.315687	0.201673	0.307455	0.466687	0.162222	0.167249
variance (normalized)	0.061212	0.01504	0.017237	0.008632	0.034416	0.065721	0.014096	0.00905
alpha	**1.445155**	**3.097929**	**3.640677**	**3.559678**	**1.594724**	**1.300678**	**1.401818**	**2.406715**
beta	**1.625007**	**8.744972**	**7.891891**	**14.09105**	**3.59213**	**1.486369**	**7.239528**	**11.98326**

Tab. 3: statistical parameters calculated for some LUS with land use 211 (cereal crops).

The figure 7 show the relief variability in the Rendina basin and the evidence of different region with clear homogeneous for a geomorphological point of view. The combination of Soil map (figure 8a) and Land Use (figure 8b) produced the final Land Use System (LUS) map (figure 9). The LUS map is the working based for next steps of processing for application of PESERA-L model.

The figure 10 and 11 show the variability of the alpha and beta parameters of slope spectrum: in the western and in the central part of the basin with distribution of slope spectrum more relevant for higher slope gradient.

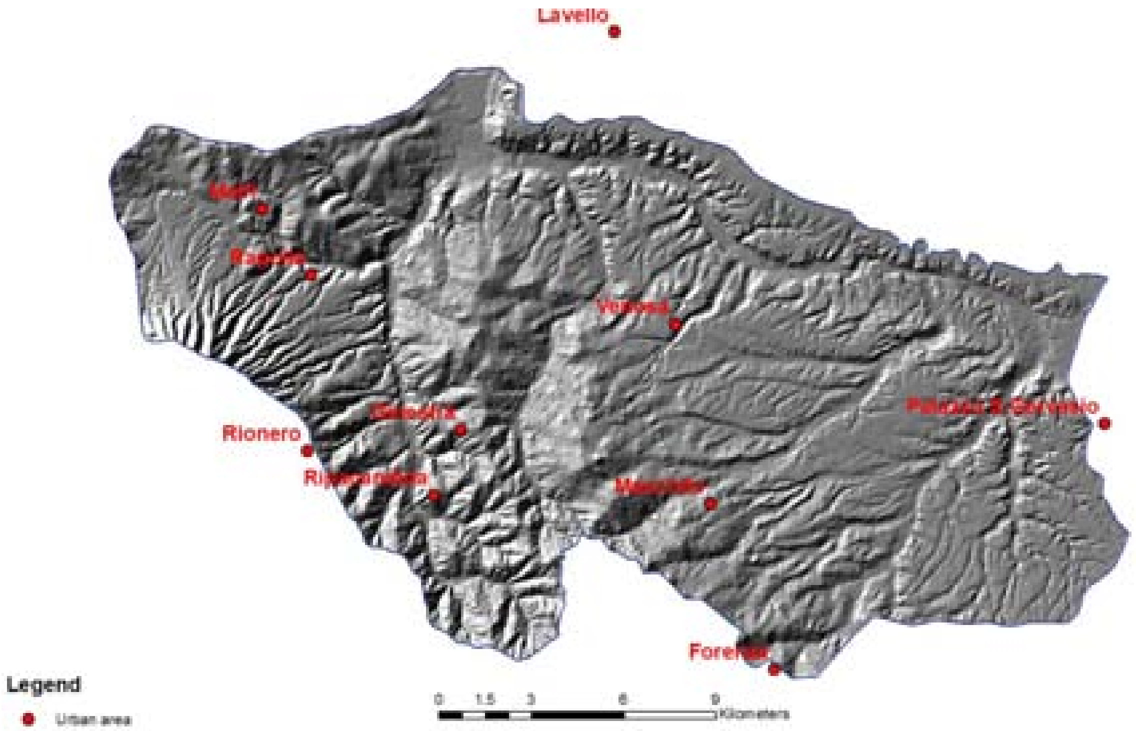


Figure 7: relief of Rendina basin .

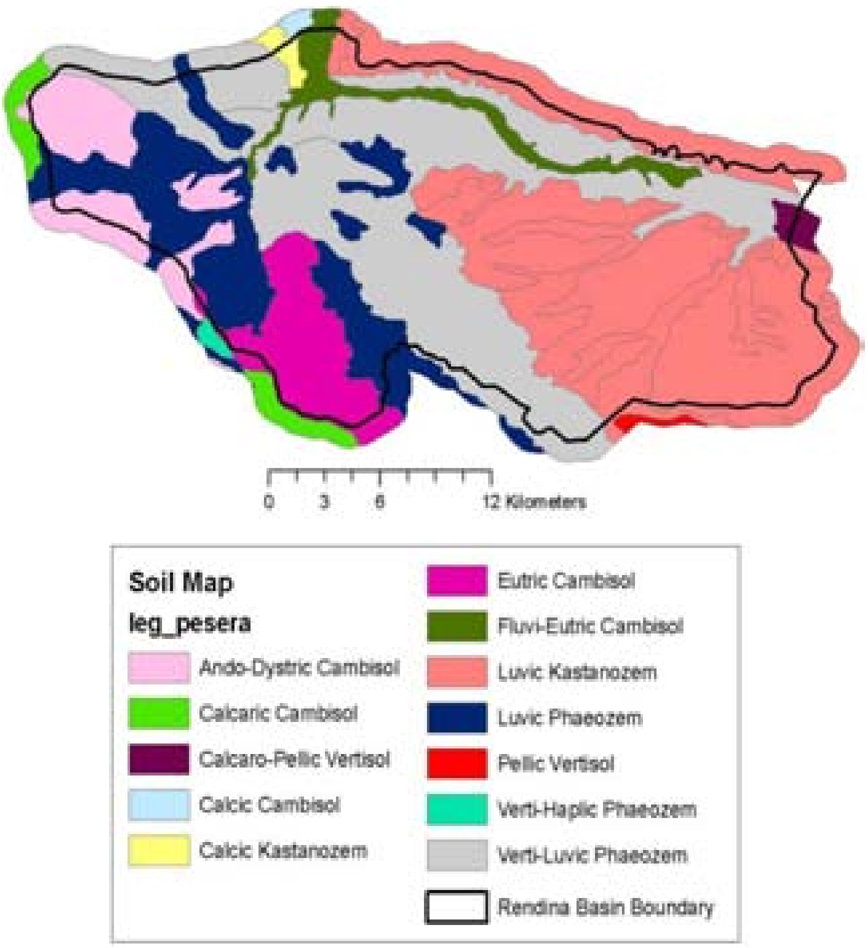


Figure 8a: Soil Unit map

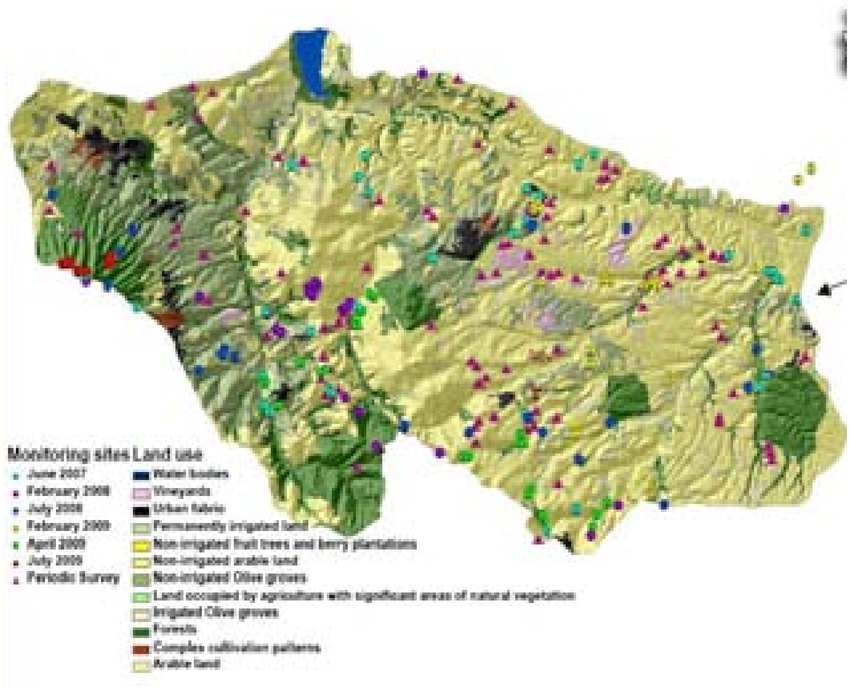


Figure 8b: Land Use

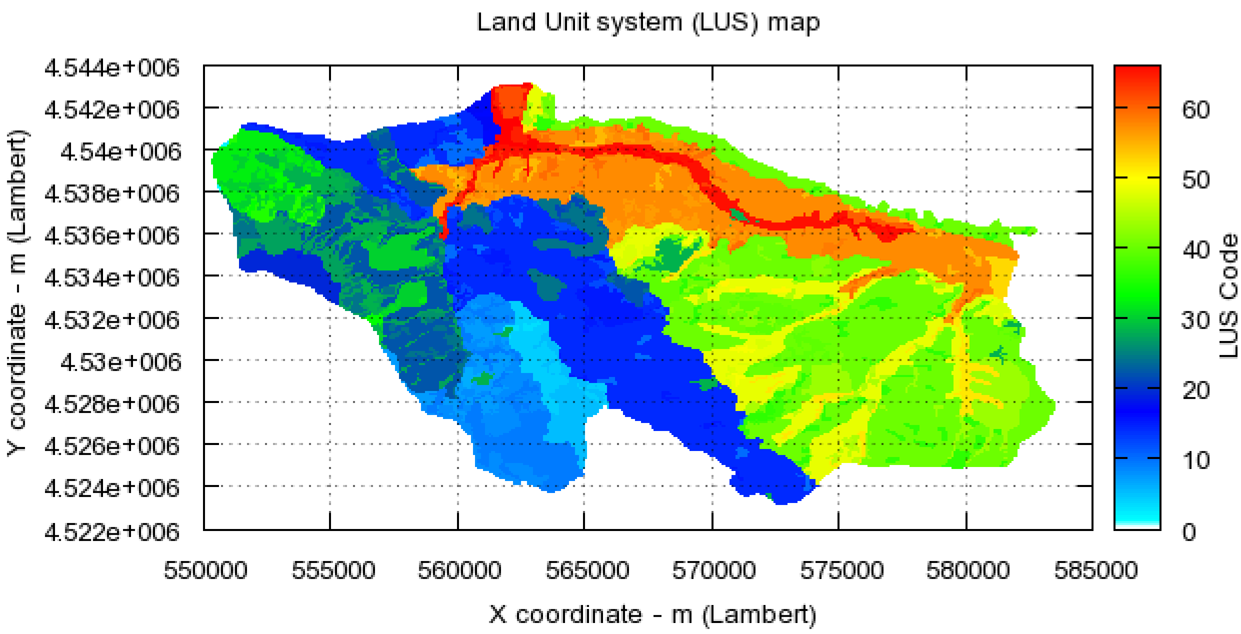


Figure 9: distribution of the 66 land unit in the rendina basin

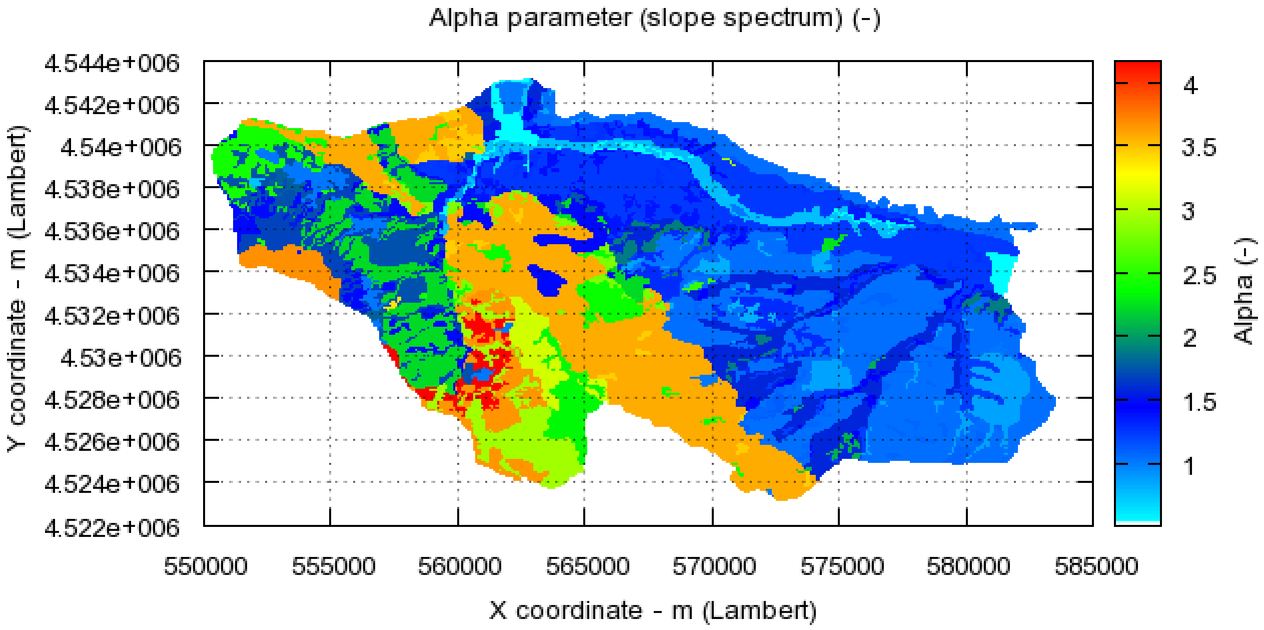


Fig. 10: Rendina basin: Distribution alpha parameters (slope spectrum model) in each LUS

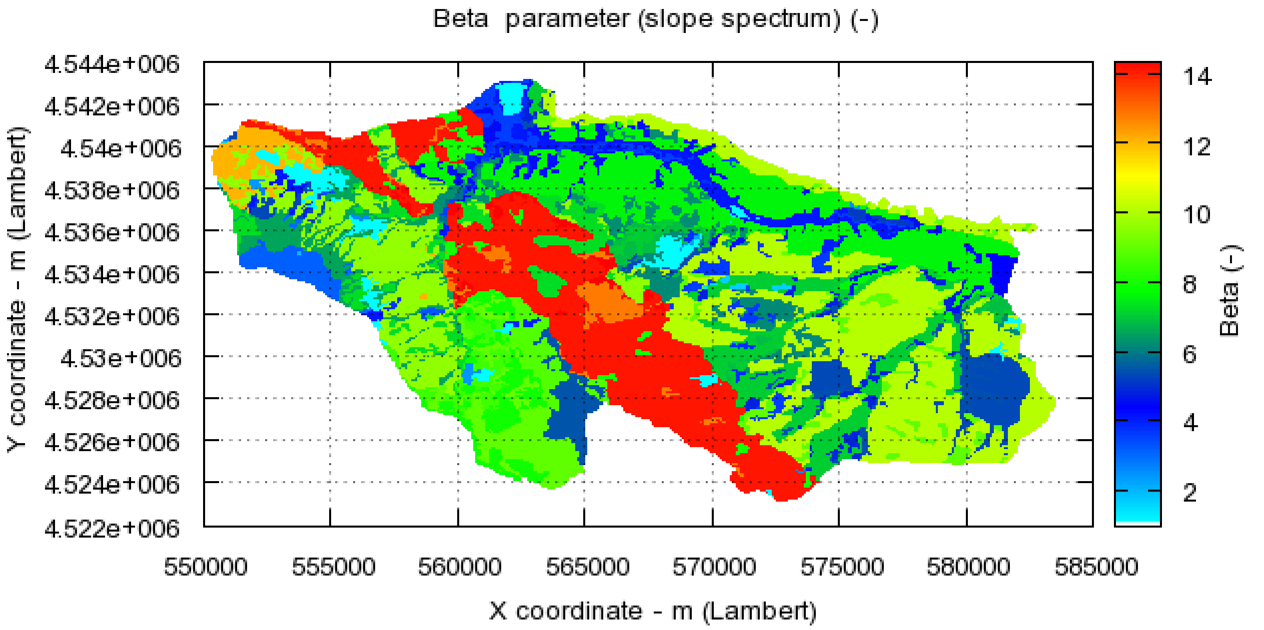


Figure 11: Rendina basin: Distribution beta parameters (slope spectrum model) in each LUS

Volume of mobilised soil mass

The territory subdivided in homogeneous LUS (partly according to WB1 WOCAT/LADA mapping criteria) is the base for the application of the PESERA –L component for the assessment of sediment contribution due to shallow mass movements.

For each LUS we assign, a range [min , max] for the different geotechnical parameters (e.g. angle of internal friction, cohesion, bulk density, depth of soil etc). The slope gradient spectrum was modelled with the Beta Distribution (figure 12).

As final result, for each LUS we obtain a distribution of Fs values and finally a Ψ value that represents the probability to have instability of the soil cover and producing shallow landslides for a given LUS unit.

In figure 13 we have an example of application with a final probability p=0.09 (9%) to have unstable conditions (fs<1.0). Because the stochastic nature of the parameters involved in the computation the Ψ is assumed as a fraction of entire LUS area can be unstable. This concept has a main importance in the final PESERA-L application at coarse scale (100X100).

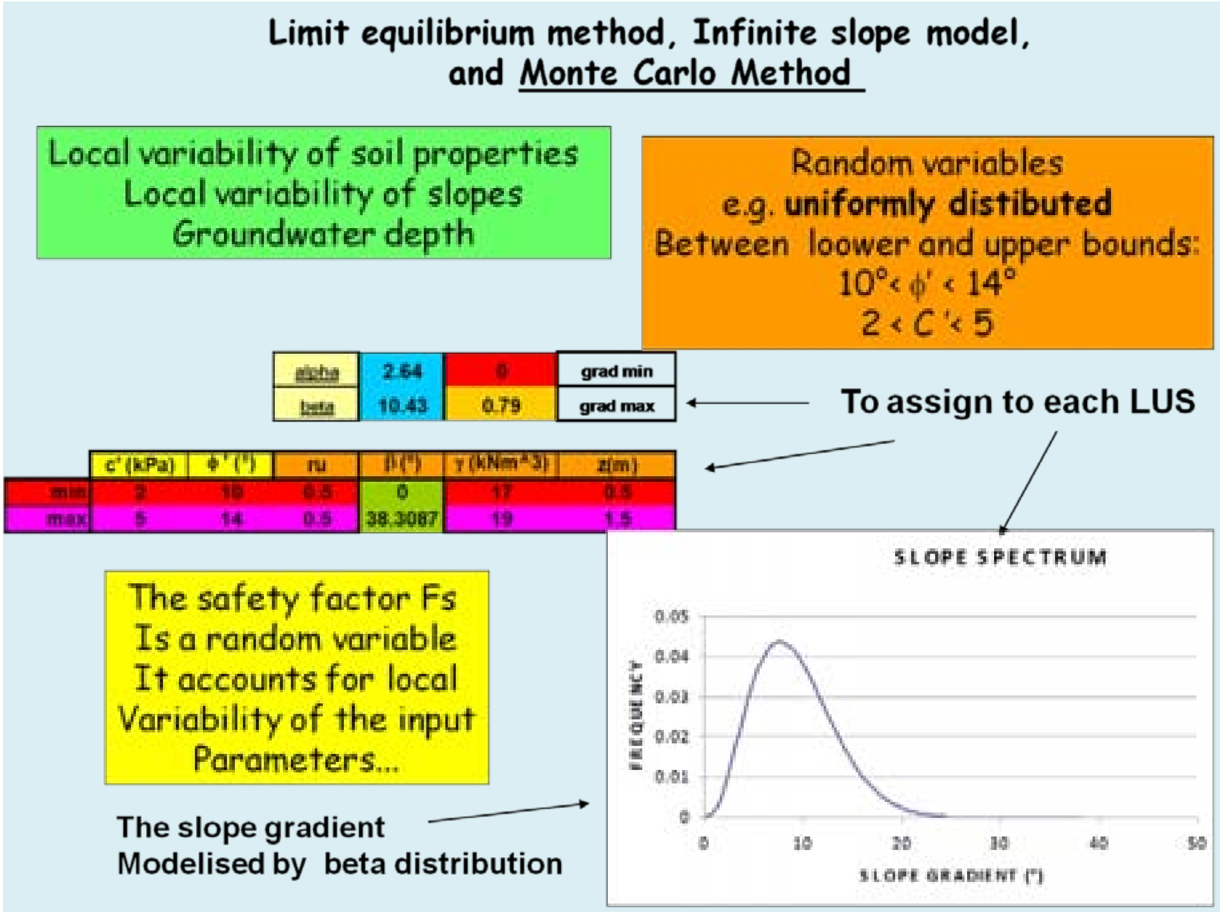


Figure 12: computation of Ψ value for each LUS: probability of unstable condition.

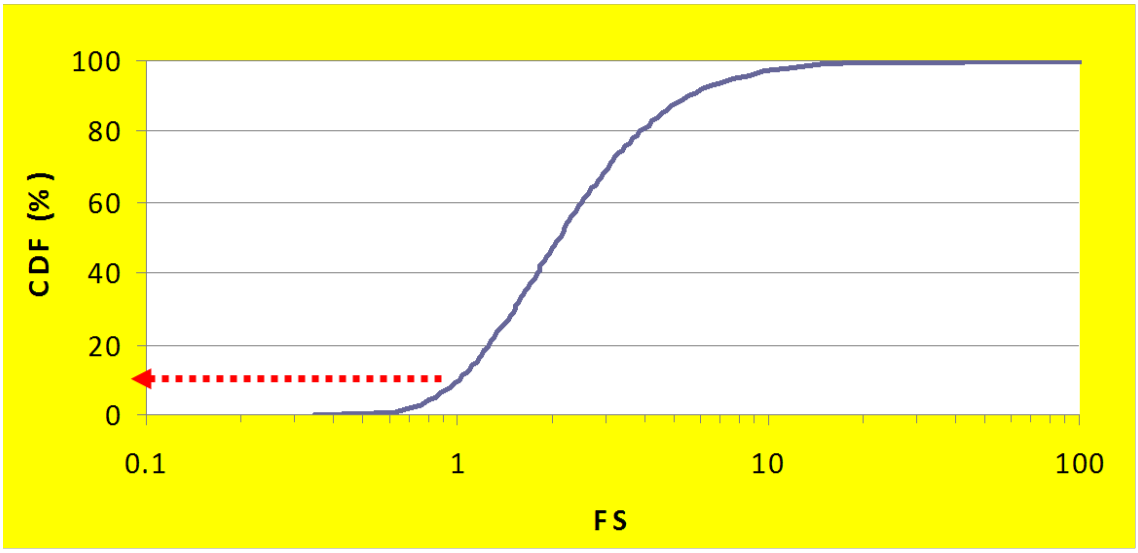


Figure 13: computation of Ψ value for each LUS: probability of unstable condition : example of application with a final probability p=0.09 (9%) to have unstable conditions (fs<1.0)

The net volume of soil mobilised for a each LUS can be computed with the following equation:

$$V = 10^6 A \ D \ \Psi \ SDR_L \qquad [6]$$

and the specific sediment yield for a single LUS (or portion of it) can be computed with:

$$SSY = \frac{V \gamma_s}{100 A \Delta_t} \qquad [7]$$

where:

V= net eroded Volume (m^3)

A= area of LUS (km2)

D= average depth of landslides (m)

Ψ=fraction of area potentially unstable (-)

SDR_L= sediment delivery ratio from landslides (-)

γ_s=soil unit weight (Mg/m^3)

Δ_t = average annual frequency of shallow landslide events (yr)

SSY= specific sediment yield from hillslope [Mg/ha/yr]

The previous equation can be simplified for the final application in the following form:

$$SSY = \frac{10^4 \ D \ \gamma_s \Psi}{\Delta_t} SDR_L \qquad [8]$$

The average depth of landslide (D) can be obtained by direct observation in field or taking the average value used in the Montecarlo simulation. Δ_t represents the inverse of yearly frequency of shallow landslide events (e.g. 1 means one event for year, 0.5 means two events for year, 2 means one events each two years …).

The sediment delivery factor SDRL is the last and fundamental component of the model in eq. 8. that must be defined in details.

Sediment delivery of mobilised soil mass (SDRL) modelling and assessment

Only a portion of the mobilised soil mass due to shallow landslide reach the hillslope bottom or a permanent drainage network element. The degree of mobility of soil mass and the impedances in the downslope route influences the amount of soil mass that contribute to sediment yield (figure 14)

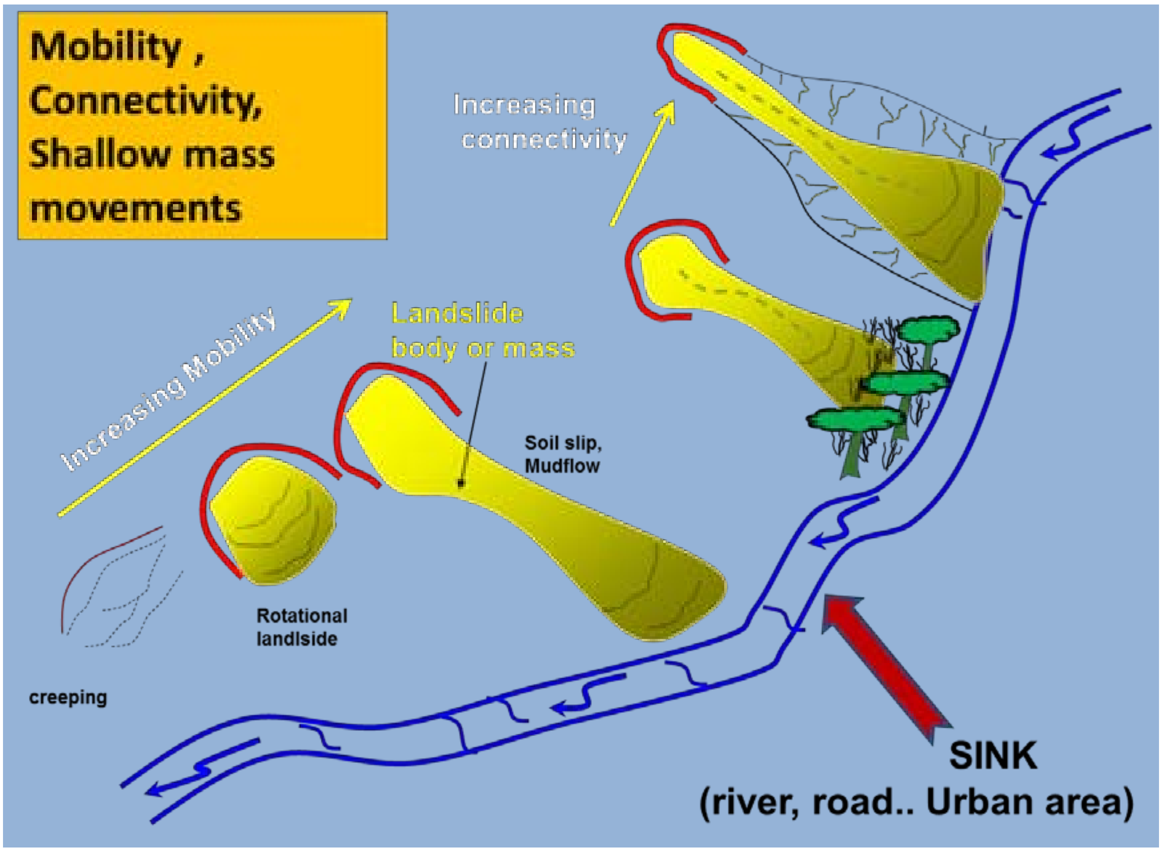


Figure 14: basic concepts of landslide mobility and connectivity.

When we have a mobilised soil mass poorly connected the fraction that contribute to SY should be reduced due the condition of the surface along the downslope route. This approach is defined form Borselli et al. (2008), where an definition of sediment flow connectivity and a index of connectivity was given. Borselli et al.(2008) define an index of connectivity obtained with an evolution of previous definitions and connectivity indexes present in literature. The authors produces a set of examples of application for sediment flow at hillslope scale and at watershed scale. Present approach to SDRL assessment, that we develop, derived integrating all the contributes by the works of Ferro and Macapilli (2000), Borselli et al.(2008) that are specific for sediment delivery in water erosion context and from Miller and Burnett (2008) that is specific for debris flow connectivity.

Following this approach the fraction (or probability) of sediments delivered at stream ,or at hillslope bottom, due to mobilised soil mass can be expressed by a Sediment delivery ratio due to landslide processes (SDRL):

$$SDR_L = e^{-\lambda D_{dn}} \quad [9]$$

Where:

λ is the inverse of average of observed runout length $\bar{L}_r$ of shallow landslides;

D_{dn} is the modified downslope component of the IC index of connectivity proposed by Borselli et al. (2008).

D_{dn} has the dimension of length and is the weighted distance of total downslope route from any position in hillslope until to nearest local sink or permanent stream. The D_{dn}

Is computed from the following set of equations

$$D_{dn} = \sum_i \frac{d_i}{W_{LU_i} W_{S_i}} \quad [10]$$

And where:

d_i is the i-th fraction of length (m) along the flow direction path until the nearest sink

W_{LU_i} is the weighting factor that depend of the local land use (e.g cerel crop, pasture, woods, etc.);

W_{S_i} is a weighting factor that depends from the local i-th slope gradient element.

W_{LU_i} Is assigned as constant values in the range [0.0,1.0] depending from the land use.

W_{S_i} Is computed by a sigmoid Boltzmann type equation that allow to reduce, or enhance, the mobility effect on the landslide depending the local slope gradient value S_i.

$$W_{S_i} = \frac{2}{1 + e^{\frac{S_0 - S_i}{k}}} \quad [11]$$

Where

S_0 is the slope gradient value where $W_{S_i} = 1.0$;

k is calibration parameter that represent slope of the sigmoid curve inflexion point.

In our study site area we assumed $S_0 = 0.20$, that corresponds approximately to 11° slope angle or the minimum critical angle where slope instability are observed, and $k = 0.04$ (figure 16)

The average runout length for each LUS is given in the figure 18. The average runout length has been obtained during the last phase of WP4 activity by aerial photo survey and field survey (multi-temporal approach) and google earth images of landslide distribution in the basin. The 50% of the basin is characterised and potentially affected by landslides with average runout length above 10m. Some LUS are characterised by an average runout of length (20- 40 m).

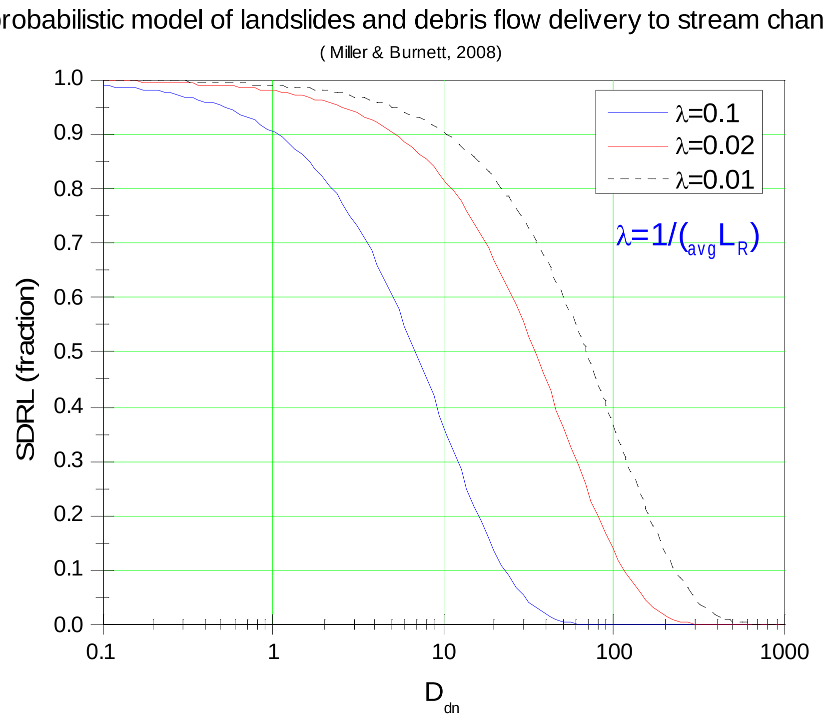


Figure 15: Miller and Burnett (2008) sediment delivery to stream approach.

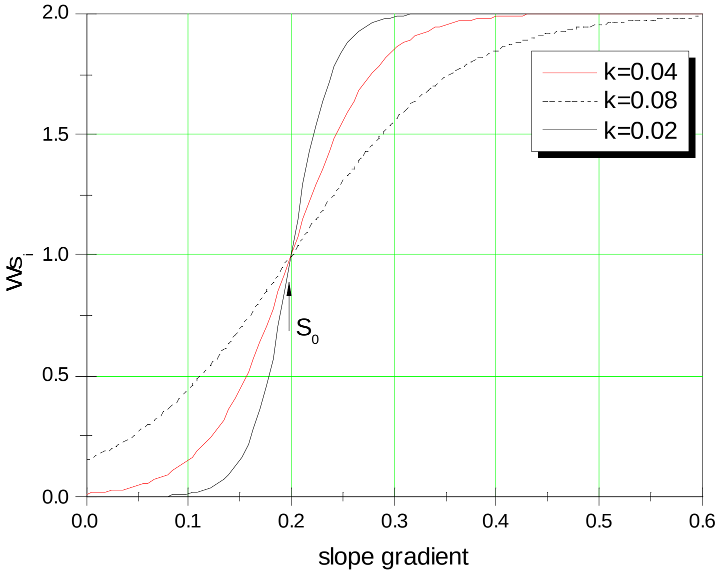


figure 16: slope gradient weighting function for D_{dn} connectivity distance.

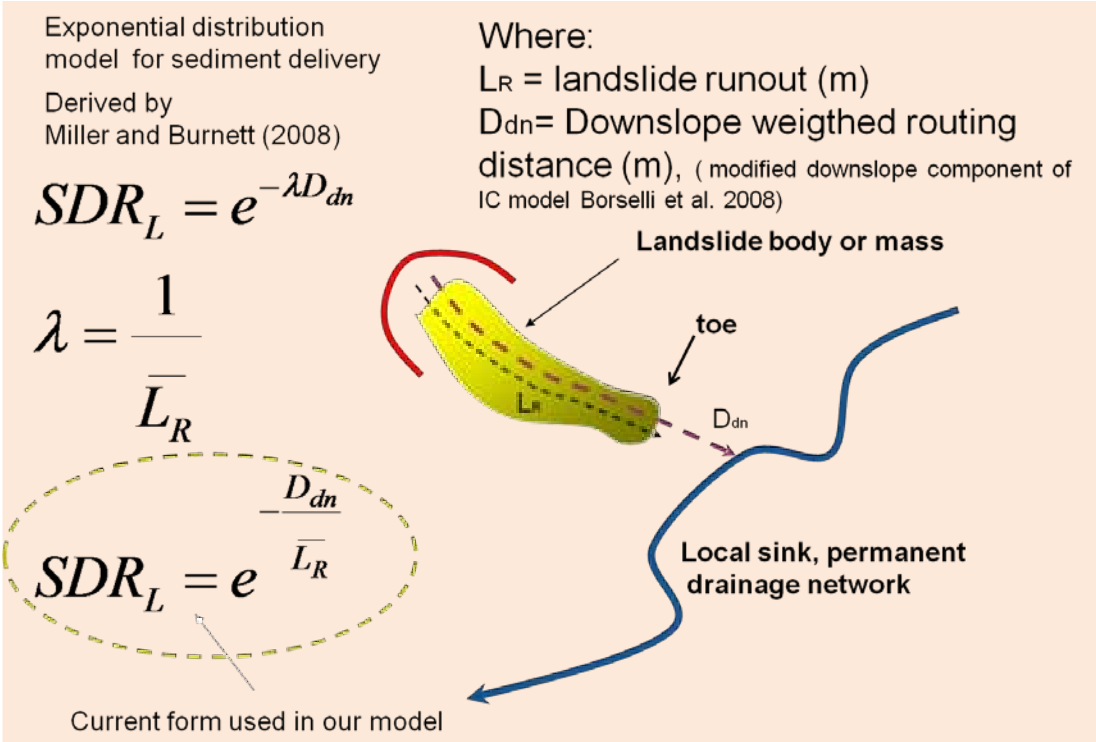


Figure 17: definitions and calculation of Sediment delivery due to landslides

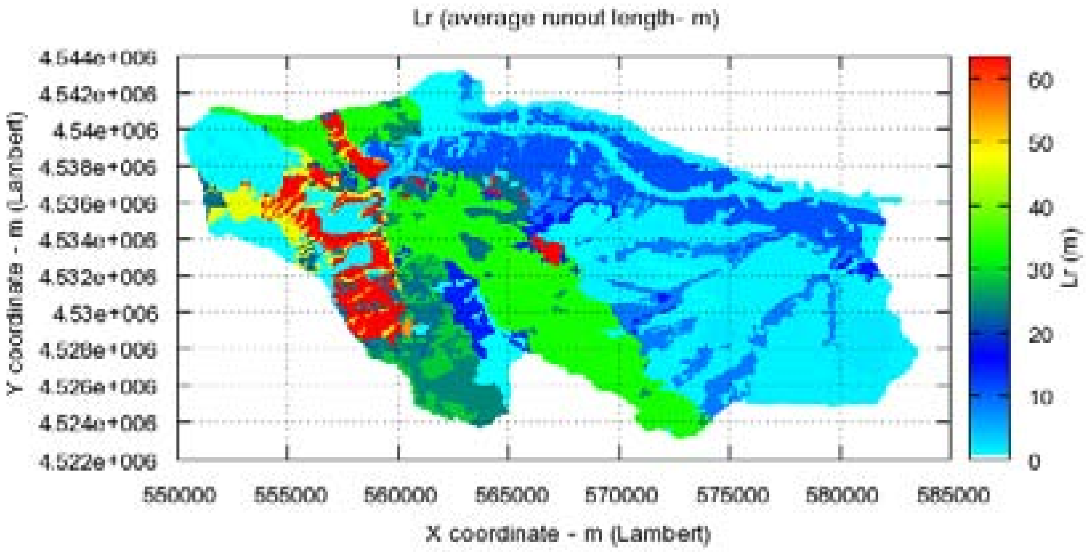


Figure 18: average runout length (Lr) map

Model calibration and application

The results of application of PESERA-L model in the Rendina study site are show and briefly discussed here.

The procedure to obtain average runout length of shallow landslide are shown in the section WP4 annual report . The value in figure 18 indicates a potential large mobility of the material. Following the model proposed by Miller & Burnett, (2008) we use the inverse of average runout length (the λ parameter, see eq. 9) as exponent of a exponential type statistical continuous distribution (see report WP4).

The application of Montecarlo simulation at each LUS in order to obtain the Ψ values produced the result given in figure 19

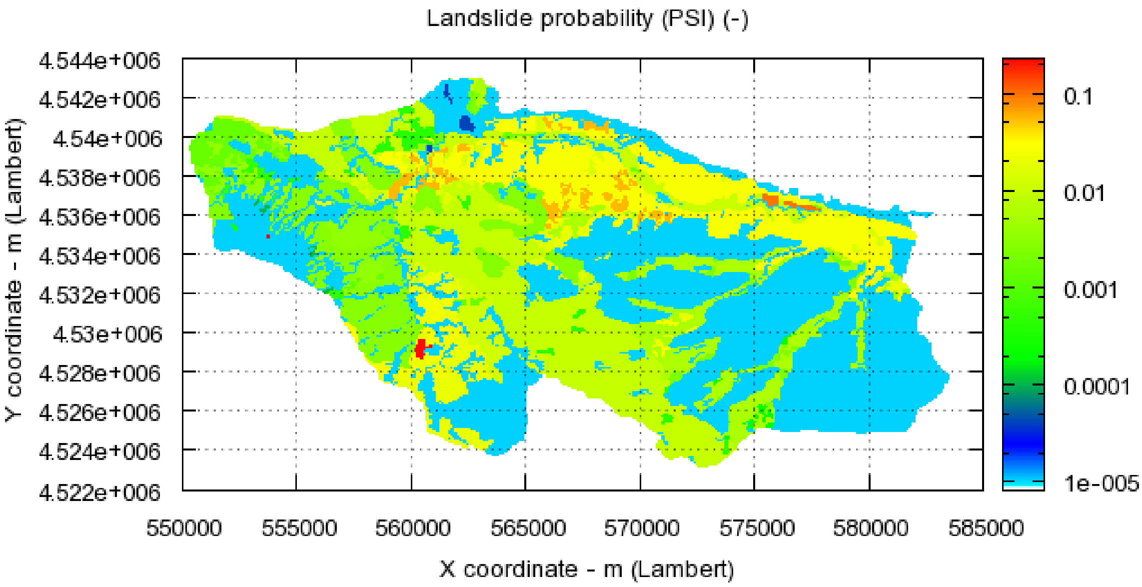


Figure 19: landslide probability (Ψ)

We observe the prevalent instability degree in the central and south area of the watershed where prevails both volcanic sediment, claystone, and flysh geological formations. We have instead a limited instability in the east and north portion of the watershed. This is due to prevailing Quaternay conglomerates and continental sediments with more gentle slope gradients. The slope spectrum of each LUS influences strongly the degree of instability of each land units. The raster version of map in figure 19 with a resolution of 100X100 that is the final resolution scale of this first application of PESERA-L

The Connectivity map: the weighted downslope distance parameter.

To obtain a D_{dn} map at scale 100X100 we produced D_{dn} computation at 20X20 DEM available for the entire watershed. Then we generalised the detailed D_{dn} map by assigning at each pixel in the 100X100 map the median value of D_{dn} present within corresponding area (25 pixels) in the 20X20 raster D_{dn} map .

Figure 20 shows the logarithmic representation of the D_{dn} values in the 100X100 map. The D_{dn} values lower than 100m (log10 D_{dn} = 2) are about the 15% of the entire area and are concentrated in the areas with rough morphology or close the main streams or alluvial terrace borders. In figure 21 the final map used for the calculation of SDRL

In the figure 22 is shown the final SDRL obtained from the calculation procedure. And in figure 23is shown the final SSY in [Mg/ha/yr]. The average landslide contribution to SSY from whole the basin is 6.5 [Mg/ha/yr], This value is low but it consider the contribution of 50% of basin that contribute very few because the landslide event are rare and infrequent. In The central part instead the landslides component is not negligible and can arrive locally at 30% of whole observed average SSY of 10-11 [Mg/ha/yr] that include all soil erosion processes.

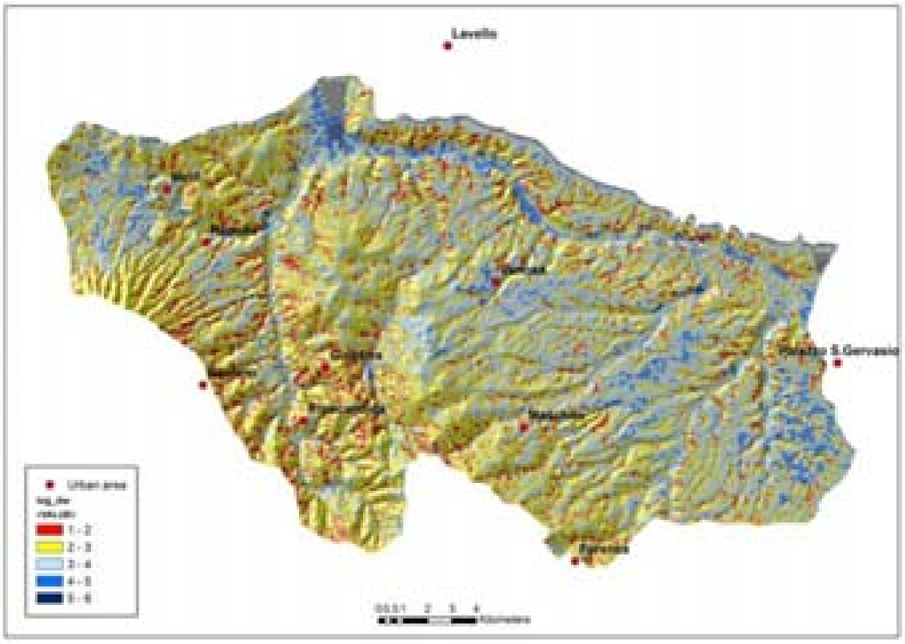


Figure 20: logarithmic representation of the D_{dn} values in the 100X100 map

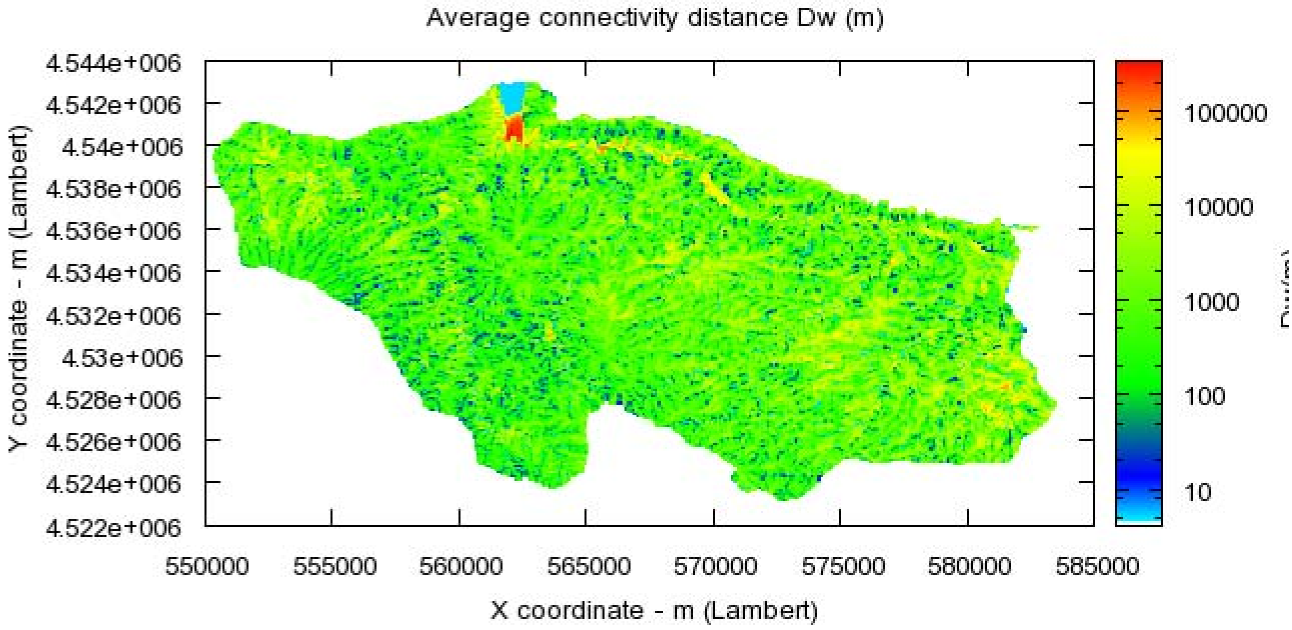


Figure 21: final map used for the calculation of SDRL

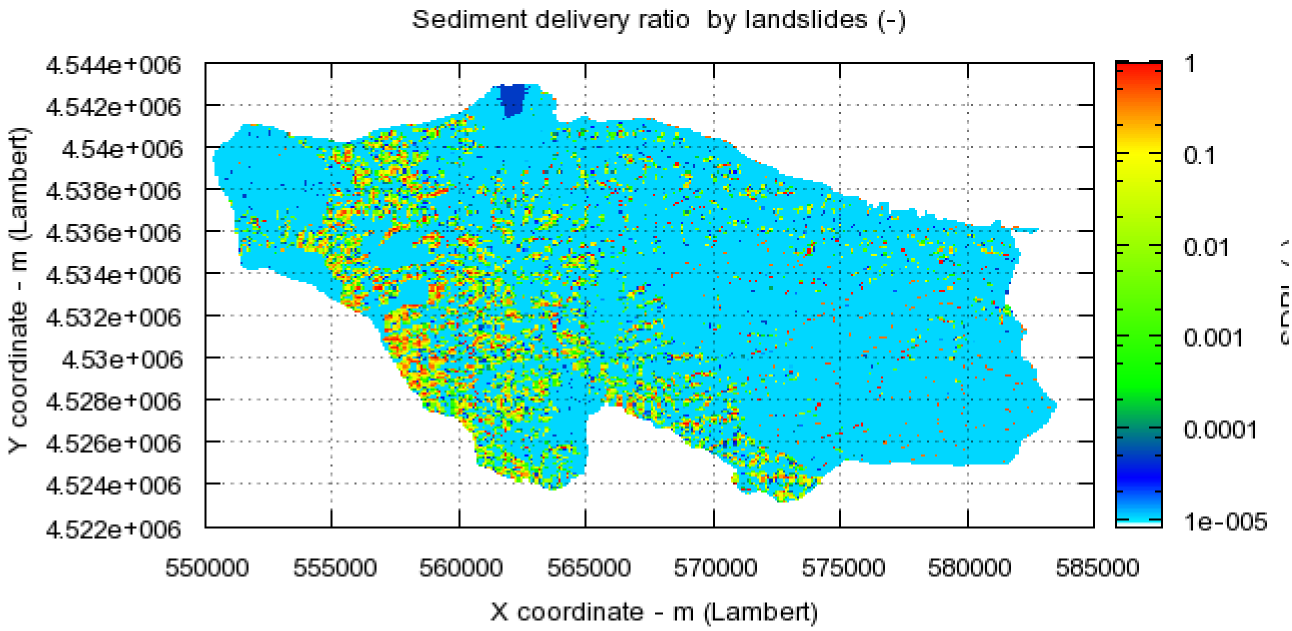


Figure 22

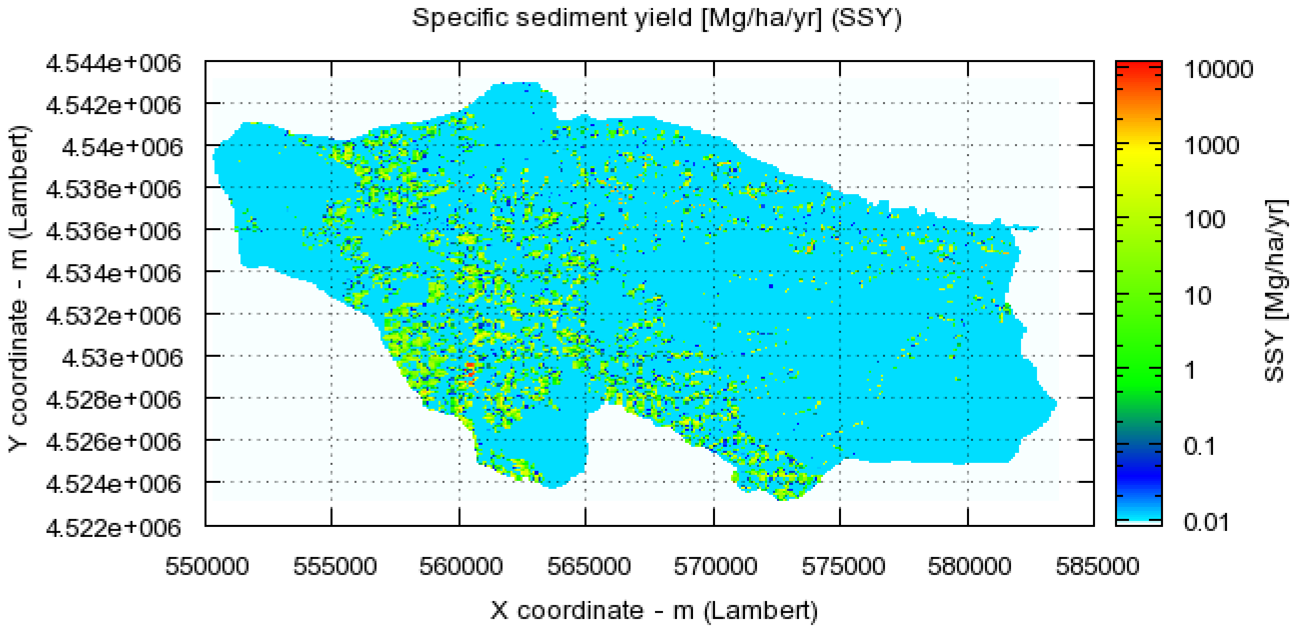


Figure 23

Figures 24and25 are zoomed portions of the map in figure 23, with some images taken in april 2009 characterised some shallow landslides.

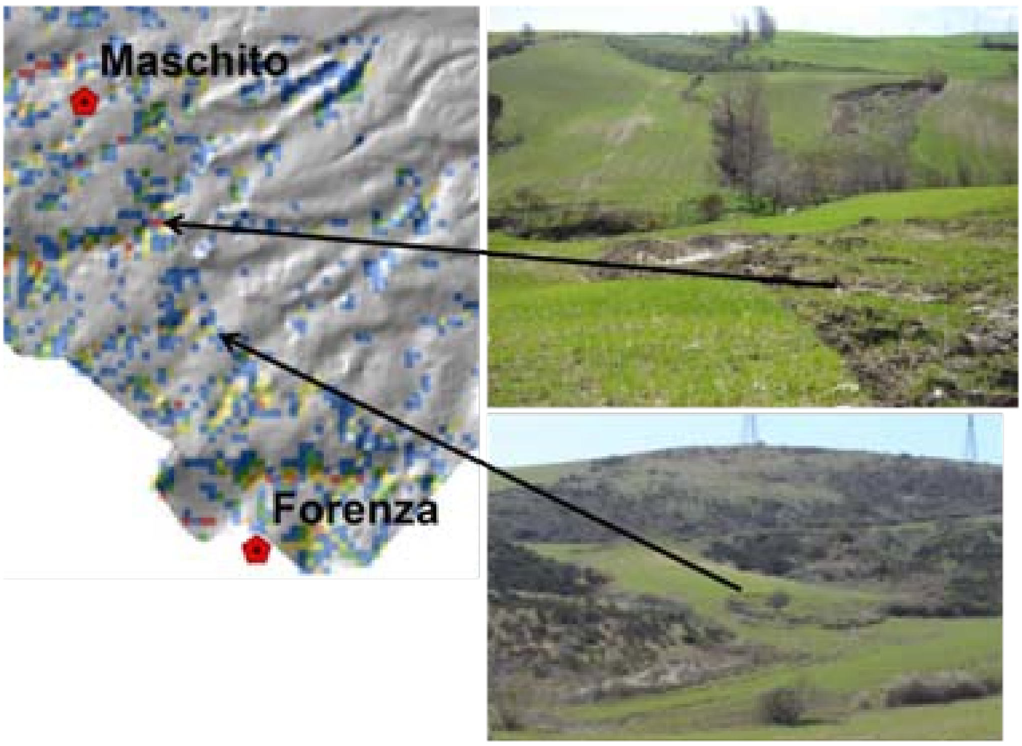


Figure 24

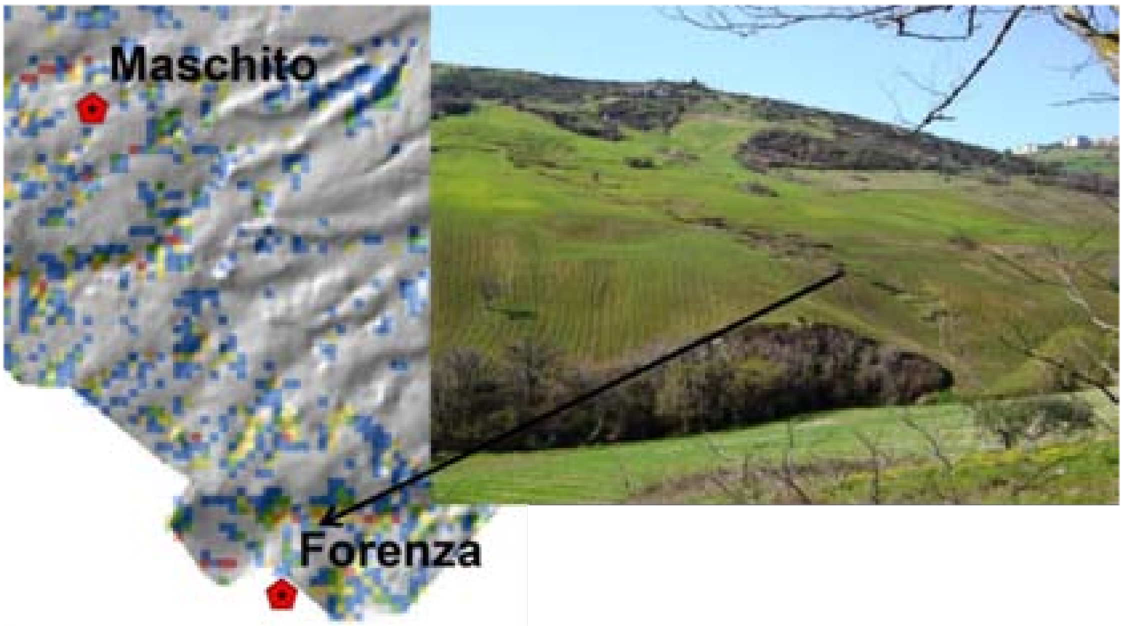


Figure 25

A simpler application of PESERA L-

The application of PESERA-L require the computation of D_{dn} map.

This may be difficult where a detailed DEM is not available. For this reason it is possible to calculate the SDRL also in a simplified form derived from eq. 9:

$$SDR_L = e^{-\frac{\overline{D_{dn}}}{\bar{L}_r}} \qquad [12]$$

In other terms the ratio $\frac{\overline{D_{dn}}}{\bar{L}_r}$ of eq. 12 may be considered as a sort of mobility parameter associated to dominant landforms/land unit characteristics and mass movement type, following the scheme show in figure 26.

More efforts are required to produce a reliable association and definition of $\frac{\overline{D_{dn}}}{\bar{L}_r}$ ratio.

In the next months we complete the calibration and produce and an Atlas of association of $\frac{\overline{D_{dn}}}{\bar{L}_r}$ with landforms/land units and an Atlas of alpha and beta parameters for slope spectrum. This will facilitate greatly the final PESERA-L application. Nevertheless the finer scale application of PESERA-L will be still possible with D_{dn} detailed map and finer scale slope gradient layer .

Figure 26

Defining an index of degradation by landslide (IDL)

A final <u>index of degradation by landslides</u> (IDL) can be obtained as final output of PESERA-L.
The IDL (show in the example in figure 27) is obtained , for each LUS predefined , by the product of Lr (average runout length) associated to LUS and the PSI (prpobability of landslide (expressed as %) or :

IDL = Lr x PSI x100 [13]

The IDL has a geomorphological significance because associate the effect of high mobility and high probability of landslides.
In our study site all the area with IDL >10 are sensitive/subject to degradation due to landsleides. (figure. 27)

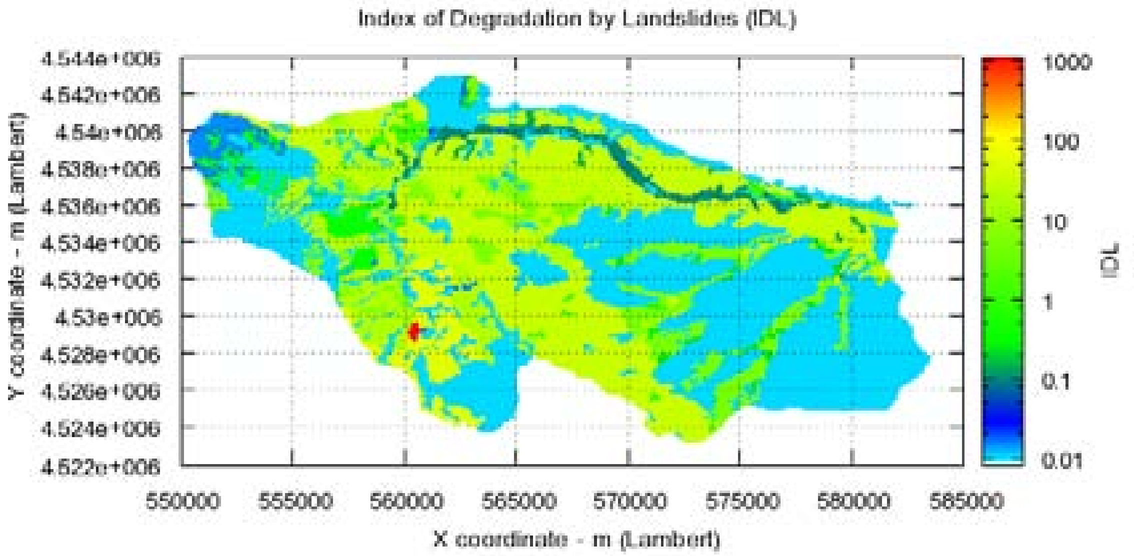


Figure 27

APPENDIX A

The PESERA-L release 1.0 (2011)

(*synthetic description and use*)

Introduction

The PESERA-L model is released as a freeware software for the scientific community. PESERA-L has been designed to operate as additional unit to well know PESERA model framework. Any way PESERA-L can operate independently for landslide degree of instability, Sediment yield, and degree of degradation by landslide assessment. PESERA-L operates (both input and output file) with common ASCII grid files (common ARCGIS, ASCII grid raster file format) and ASCII text file (CVS format) structured for an easy exchange with EXCEL spreadsheet.

The software use a graphic rendering by help of GNUPLOT 4.4.2 graphic engine (http://www. Gnuplot.org) distributed as open source (GPL license) and redistributable wihin PESERA-L.

In this way the input/output raster files can easily viewed, and exported directly by the program without more complex GIS software. A simple GUI front end allow an easy interaction with the user.

System requirements

OS: windows XP,Vista,win7 ; Ram: 2GB; space on HD 100MB

PESERA-L Graphical User's interface(GUI)

The PESERA-L has a simple interface. The figure A.1 shown the main window and figure A.2 , a view map window and the raster map plotting by gnuplot graphic rendering engine.

Figure A.3 shown the PESERA L- options Dialog.

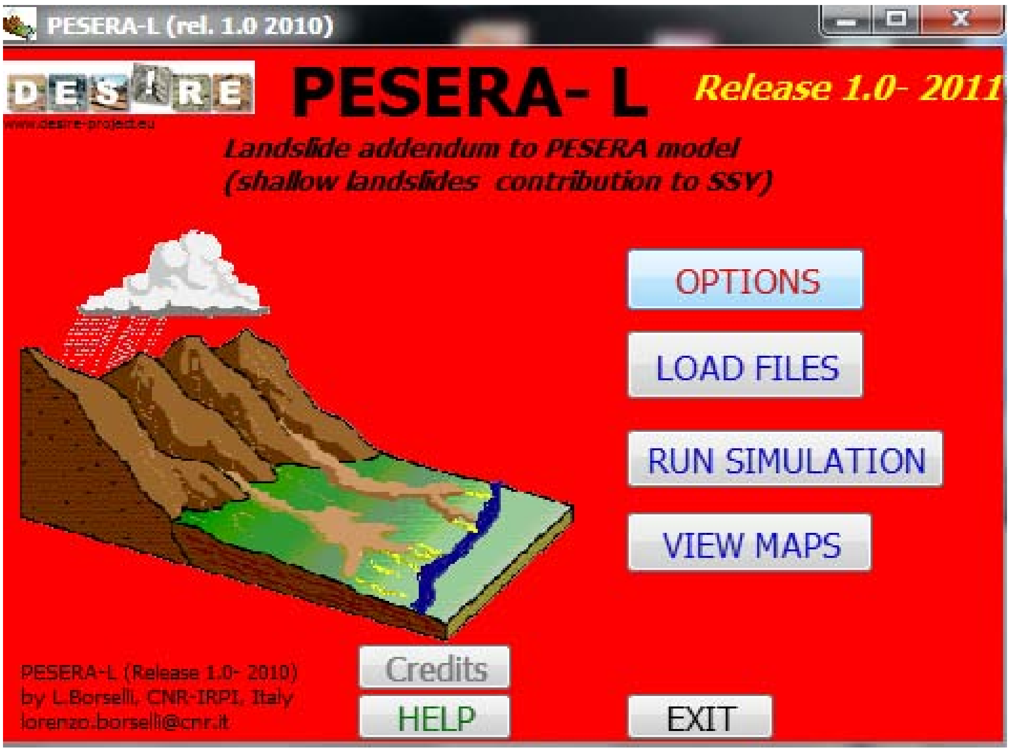


Figure A.1

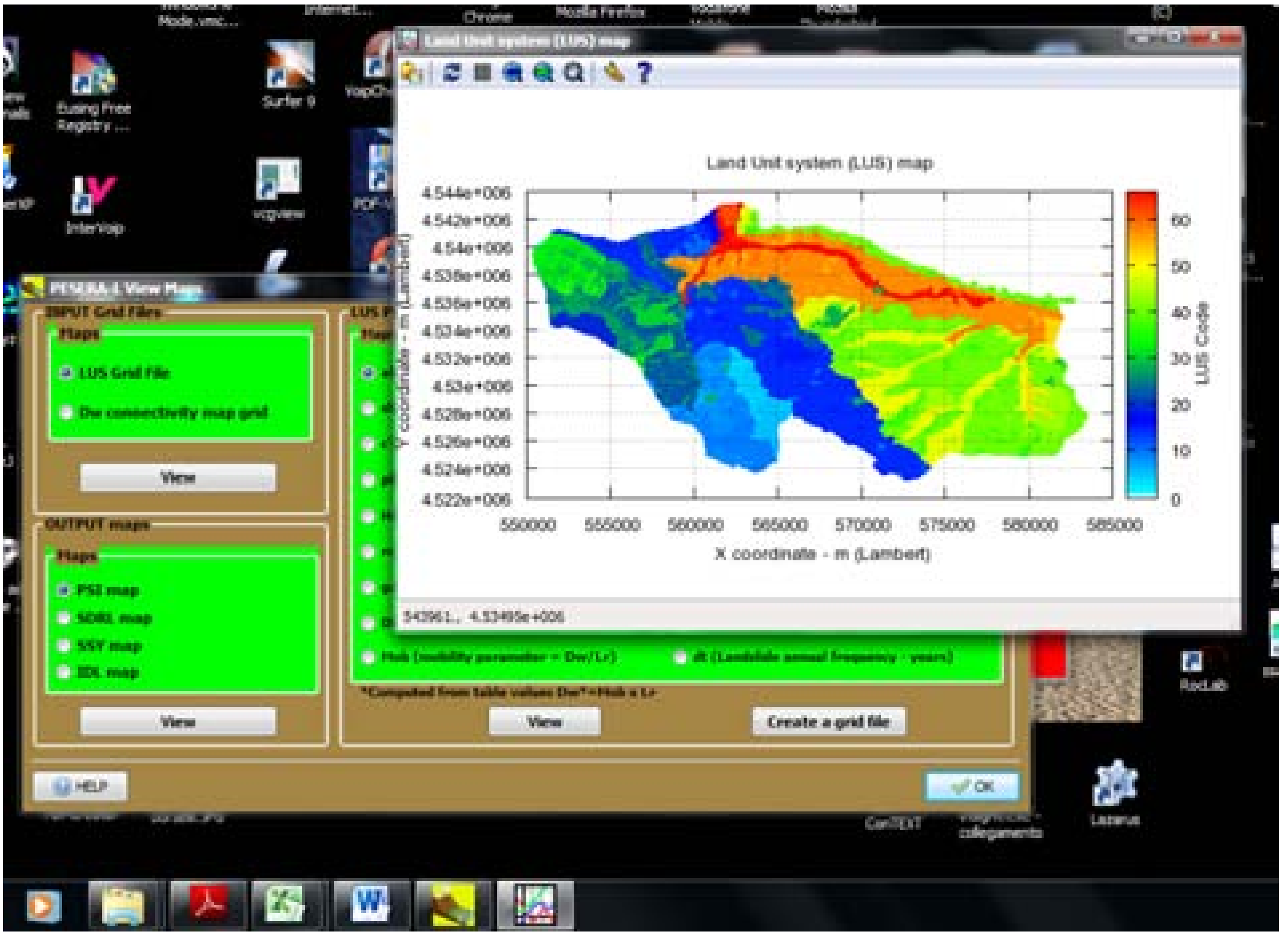


Figure A.2

INPUT and OUTPUT files

Two type of input files are required:

1. ASCII text files (.CSV) containing the table with all relevant geotechnical topographical and connectivity parameters for each LUS identified in the watershed
2. ASCII grid files (.GRD file ESRI ArcGIS compatible) for various INPUT/OUTPUT map
    a. Integer type 4 bit (for LUS input map only)
    b. Float type 8bit (all other input/output grid map with real value content)

The input and output files are enterd in the file dialog window figure A.4

Figure A.3: Pesera L- option dialog

Figure A.4 : input /output File dialog.

Monitoring Simulations

The simulation process can be monitored with two type of panel that is updated in continue. The type of monitor depends form the simulation level chosen (see figure A.5 and A.6).

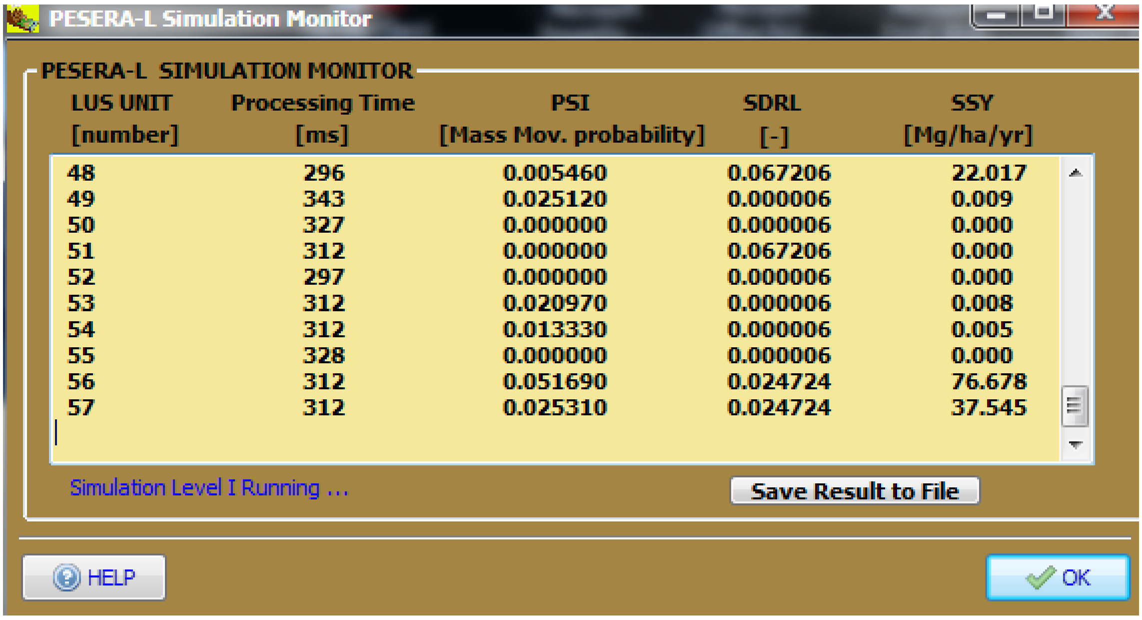


Figure A.5: monitor for SIMULATION Level I

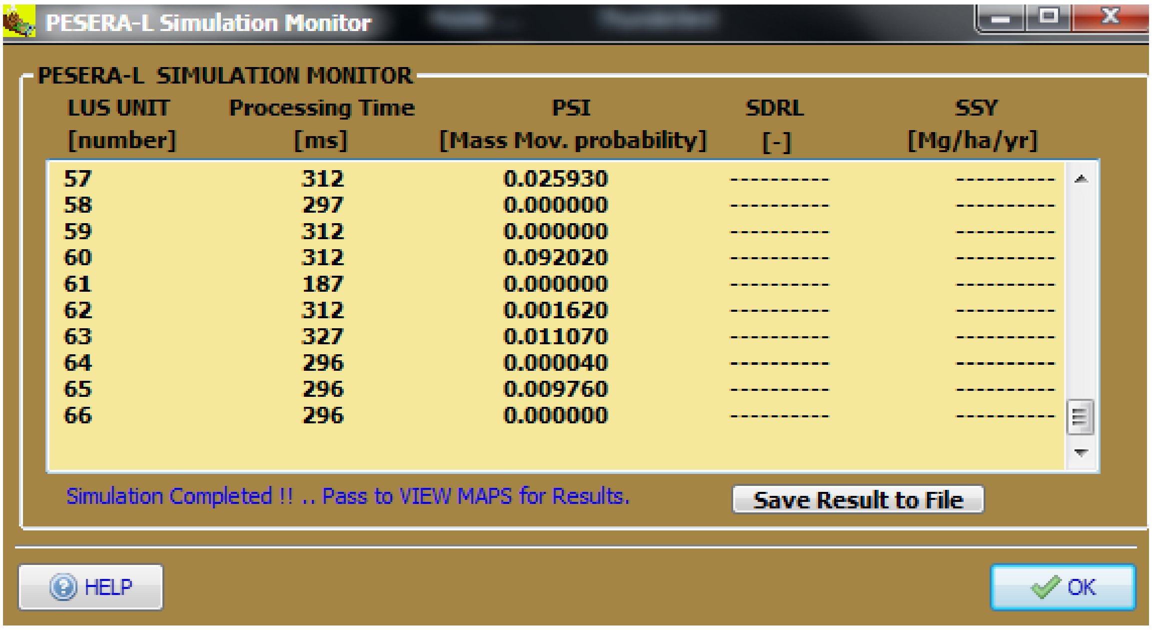


Figure A.6: monitor for SIMULATION Level II

For simulation level I is given for each LUS the PSI, SDRL, and SSY. For simulation level II is given for each LUS the PSI only because the SDRL and SSY is computed by a grid matrix computational procedure and is given only as final raster value grid file and map. (see View maps dialog.in the next section)

View maps dialog

View map dialog allow to plot raster map of all input and output files. Also for each parameters in LUS table can be viewed as raster map and optionally generated as grid file

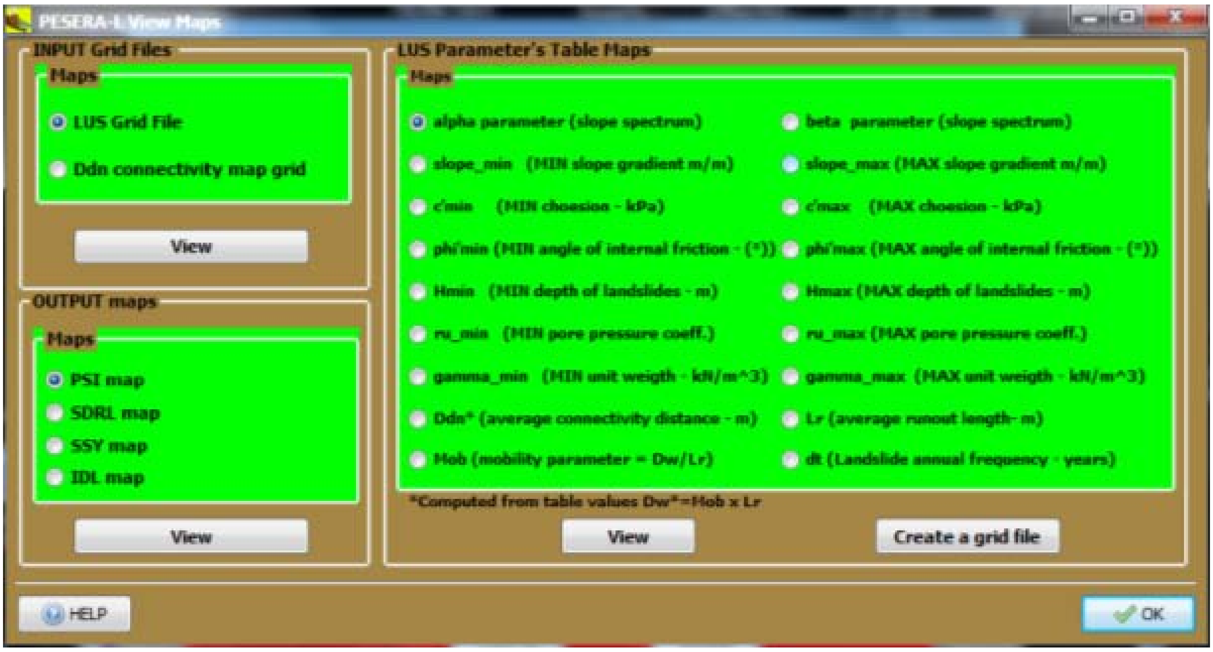


Figure A.7: view Maps dialog

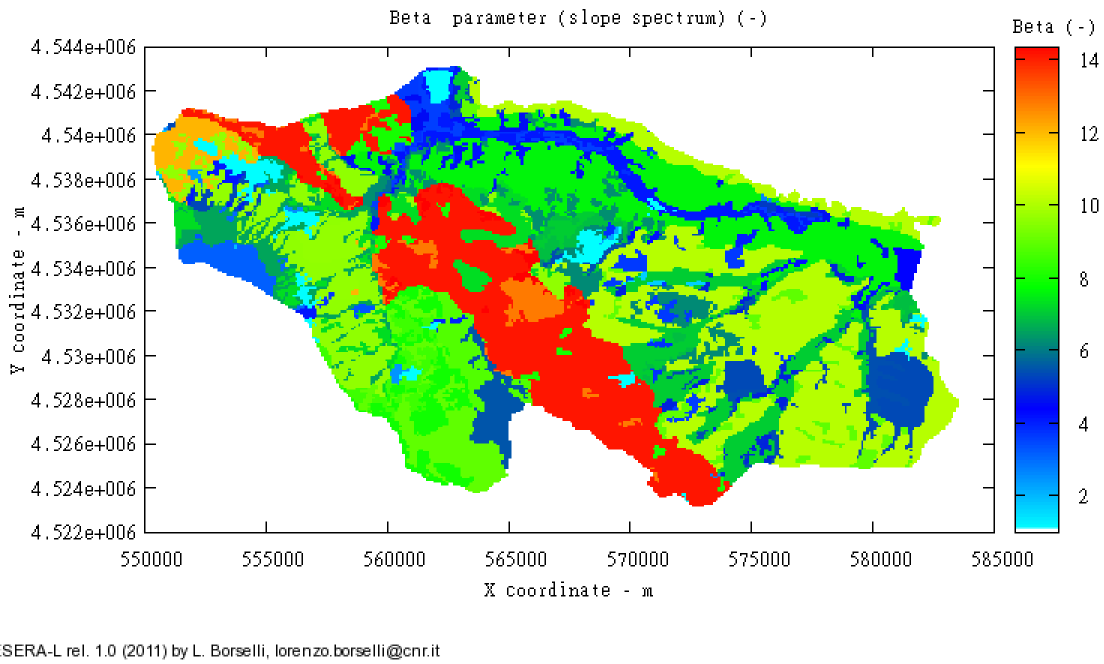


Figure A.8: raster map viewed with Gnuplot grid file rendering routine developed in PESERA-L.