Assessing soil erosion rates at vineyard scale: a study case in North-West Italy using different DEM resolutions for the LS factor computation

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ONLINE WORKSHOP ON
SOIL EROSION FOR THE EU 20 – 22 JUNE 2022 | JRC Ispra

European Commission

Introduction

- Italian vineyards are set in sloping areas
- Soil management: bare/poorly vegetated ground, spontaneous grass cover, green manure
- Increasing mechanization for crop and soil management

In Piemonte (NW Italy):

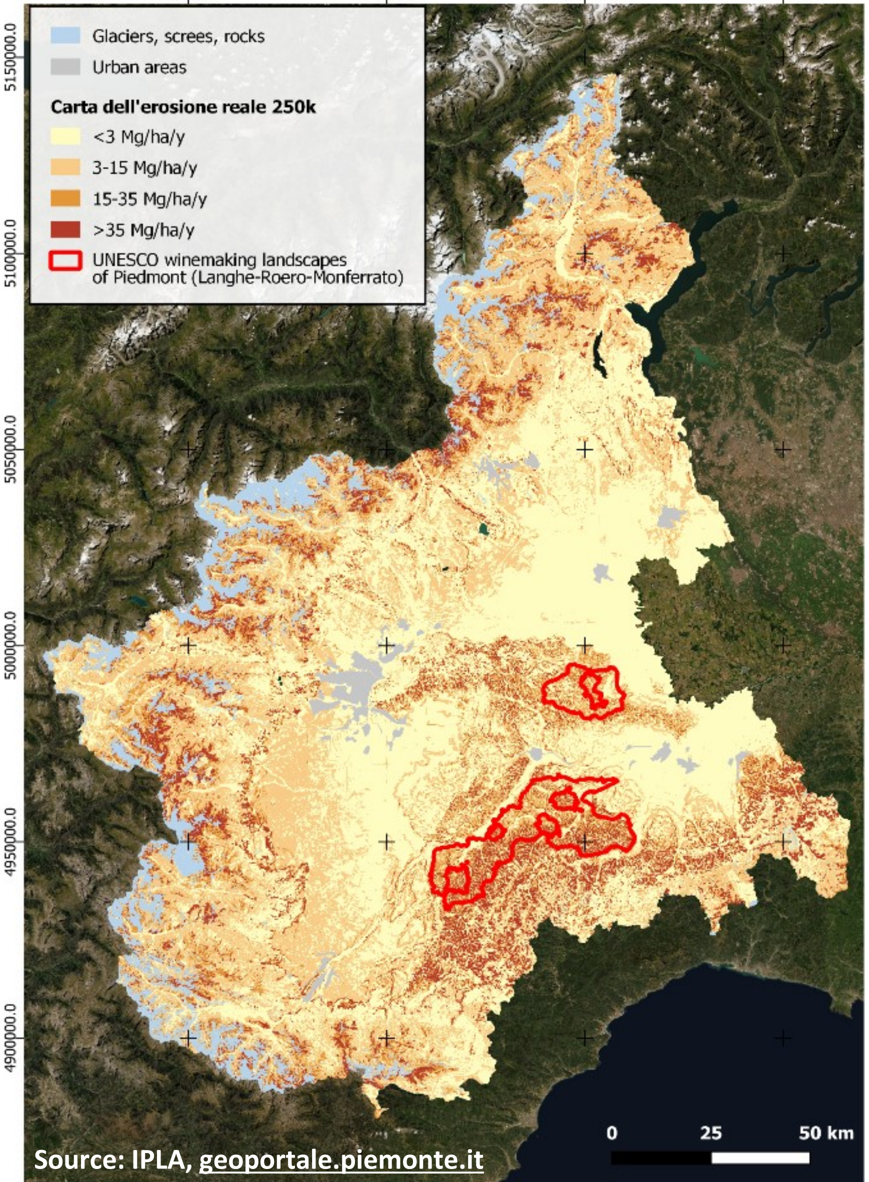
SOC stock: - 1.58 % (plain areas)

- 1.15 % (hilly areas)

(Leo et al., 2011)

Erosion rates> 15 Mg/ha*y :
- Hilly areas: 40.2%
- Plain areas: 23.6%
- Mountains: 5%

(IPLA, 2009)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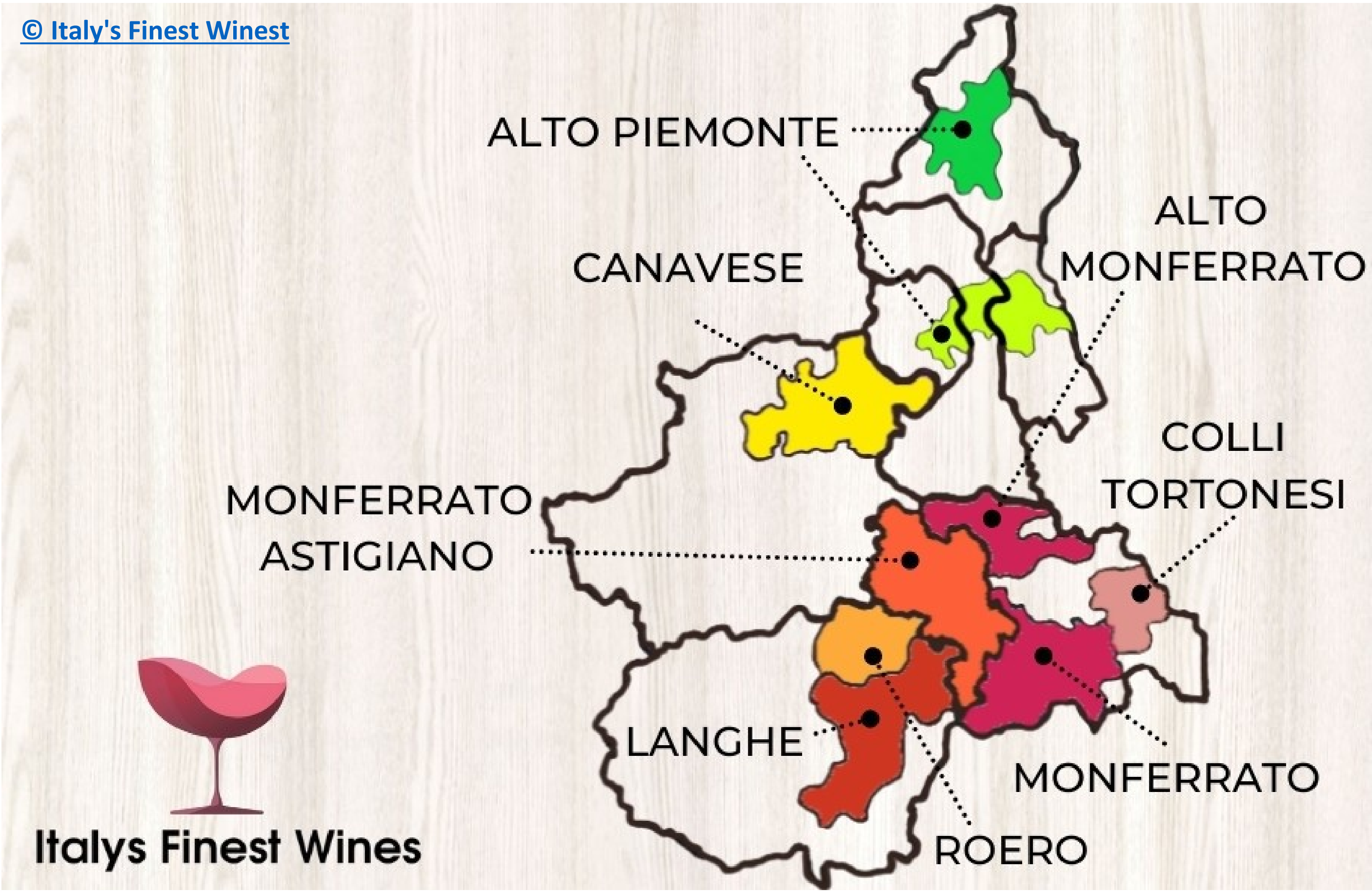
Glaciers, screes, rocks
Urban areas
Carta dell'erosione reale 250k
<3 Mg/ha/y
3-15 Mg/ha/y
15-35 Mg/ha/y
>35 Mg/ha/y
UNESCO winemaking landscapes of Piedmont (Langhe-Roero-Monferrato)
0
25
50 km
Source: IPLA, geoportale.piemonte.it


© Italy's Finest Winest
ALTO PIEMONTE
ALTO MONFERRATO
CANAVESE
COLLI TORTONESI
MONFERRATO ASTIGIANO
LANGHE
MONFERRATO
ROERO
Italys Finest Wines

Revised Universal Soil Loss Equation

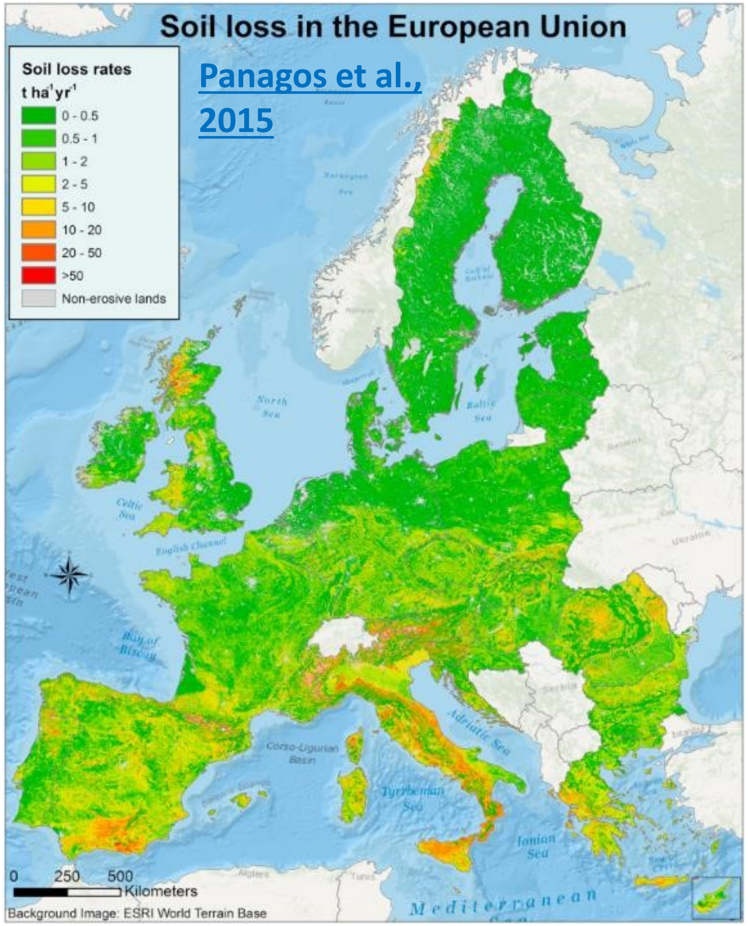
(Wischmeier & Smith 1978); (Renard *et al.* 1997)

$$A = R * K * L * S * C * P$$

A	average annual soil loss per area unit	(Mg ha^{-1} y^{-1})
R factor	rainfall erosivity	(MJ mm ha^{-1} h^{-1} y^{-1})
K factor	soil erodibility	(t h MJ^{-1} mm^{-1})
L factor	slope length	(dimensionless)
S factor	slope steepness	(dimensionless)
C factor	cover and management	(dimensionless)
P factor	support practices	(dimensionless)

- Empirical model, yet still one of the most used
- Applications for different scales of investigation
- Data can be derived from:
    - open source databases (local, ESDAC, …)
    - field observations

LS factor is among the most important factors, and can be derived from GIS data (*e.g.*, Digital Elevation Models -DEMs-)



S factor

- Effect of slope steepness on soil erosion
- Ratio of soil loss from field gradient to that from a 9% slope
- Affected by vegetation cover and soil particle sizes

L factor

i) distance from overland flow origination to the point where slope decreases enough and deposition begins
ii) runoff water entering a well-defined channel part of a drainage network or a constructed channel

Time-consuming for field scale assessment
GIS-based procedures can help reducing operational times

… quality of data sources is essential, → DEM resolution plays a key role (Fijałkowska, 2021, Raj et al., 2018)

… and computational procedures as well → Multiple and Single Flow Direction Algorithms (MFD/SFD) (Bircher et al., 2019)

Objectives of the research

For a given study area:

- Different Digital Elevation Models (DEMs) available with different spatial resolution
- Different algorithms to assess LS

Operator-made
–vs–
GIS-based
computational procedures

i) comparing LS estimates;

ii) testing contribution of DEM resolution to LS accuracy;

iii) suitability of DEM(s) and GIS to replace operator-made measurements for LS

iv) assessing the role of LS in soil loss estimation within the RUSLE methodology

Study Area

- Pleistocenic fluvial terraces
- Highly altered gravel, sandy / silty-clay deposits with red alteration products
- Texture: clay / clay-loam
- Typic Ustorthents, fine-loamy, mixed, calcareous, mesic (USDA 2010) or Dystric Cambisols (FAO/ISRIC/ISSS 1998)
- Slopes of the fields:
  - min: 5.1%
  - max: 28.3%
- 1-2 tillages every year in CT
- Mowings in GC during season

Municipality of Carpeneto
Province of Alessandria
Piemonte, Italy

44°40'N, 8°37'E
296 m above sea level

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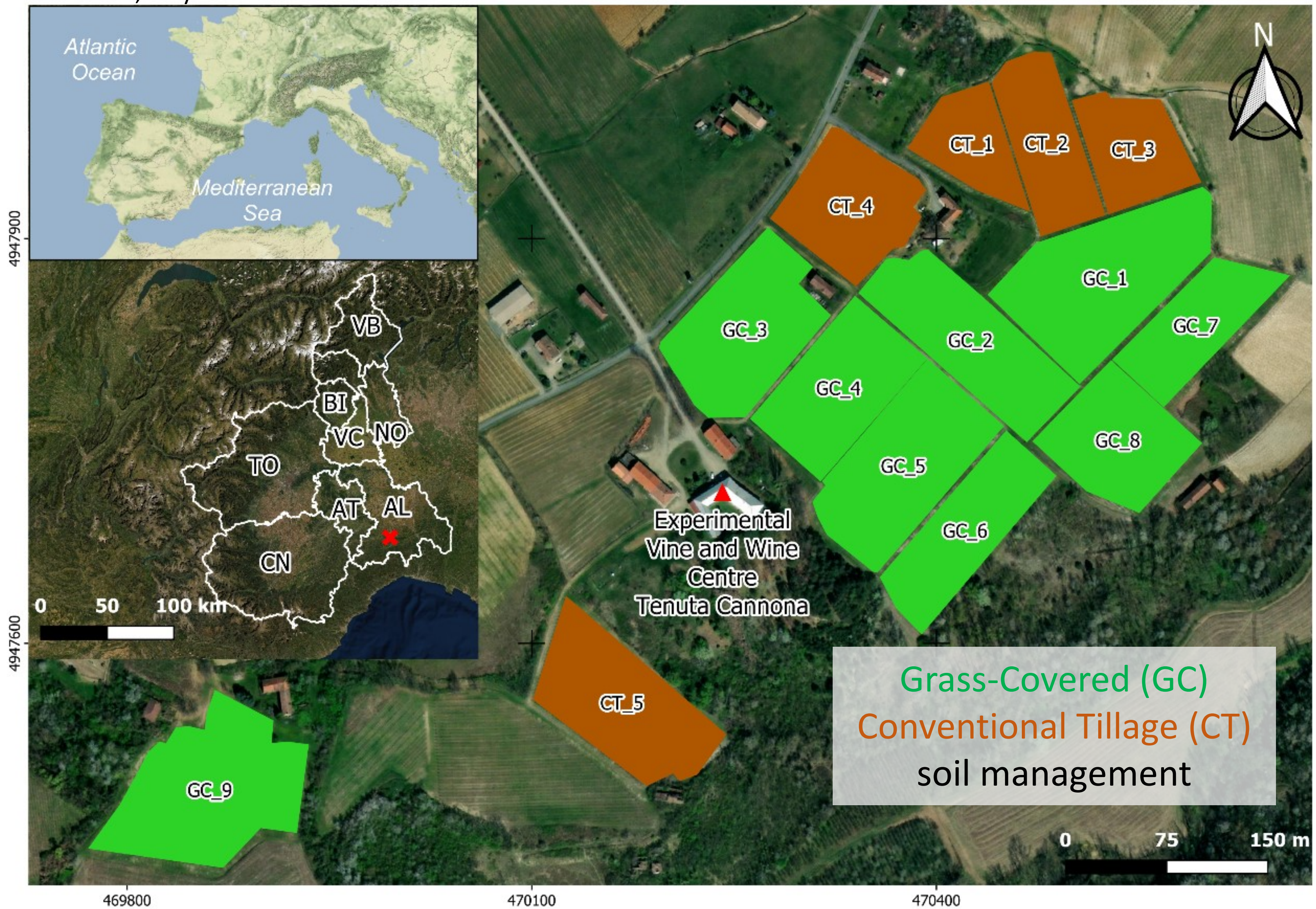
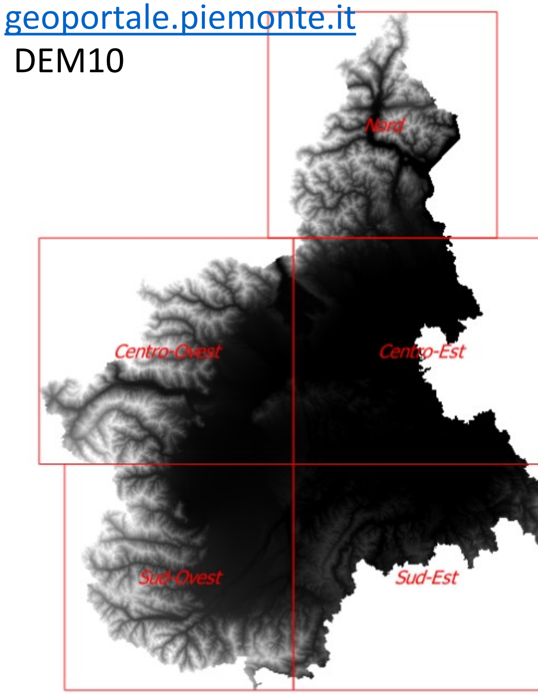
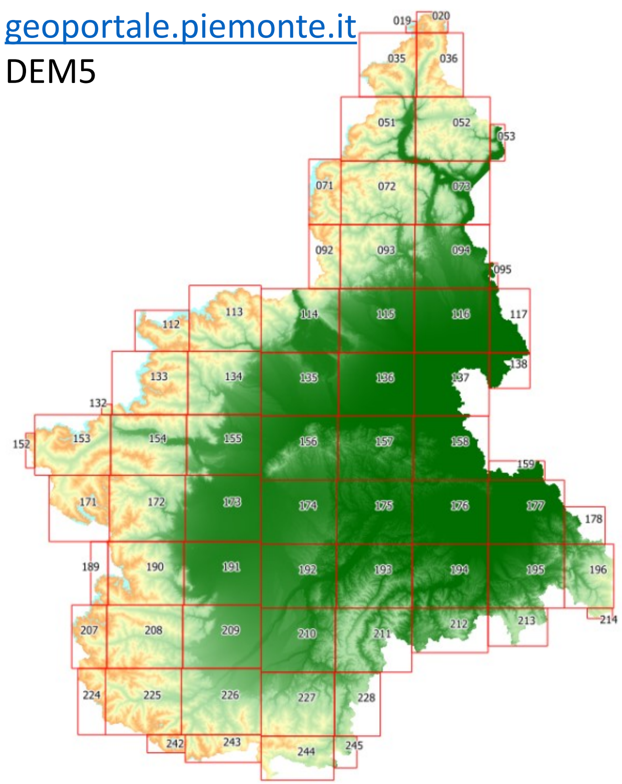


Data - DTM

geoportale.piemonte.it
DEM10



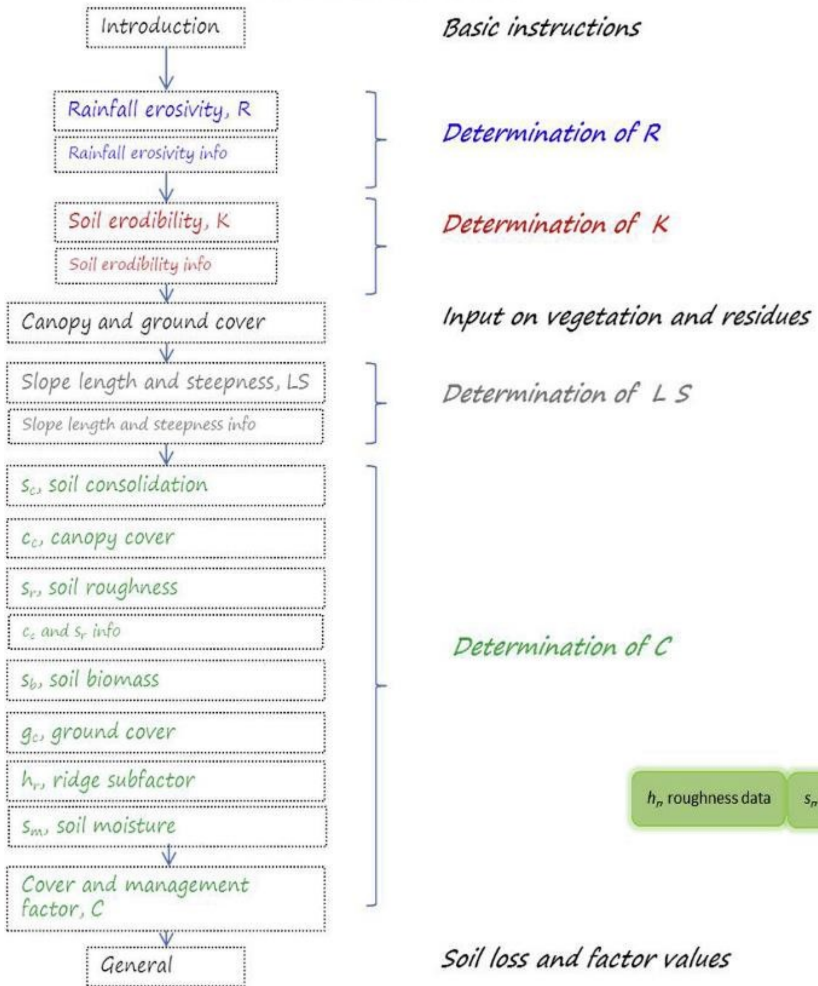
geoportale.piemonte.it
DEM5



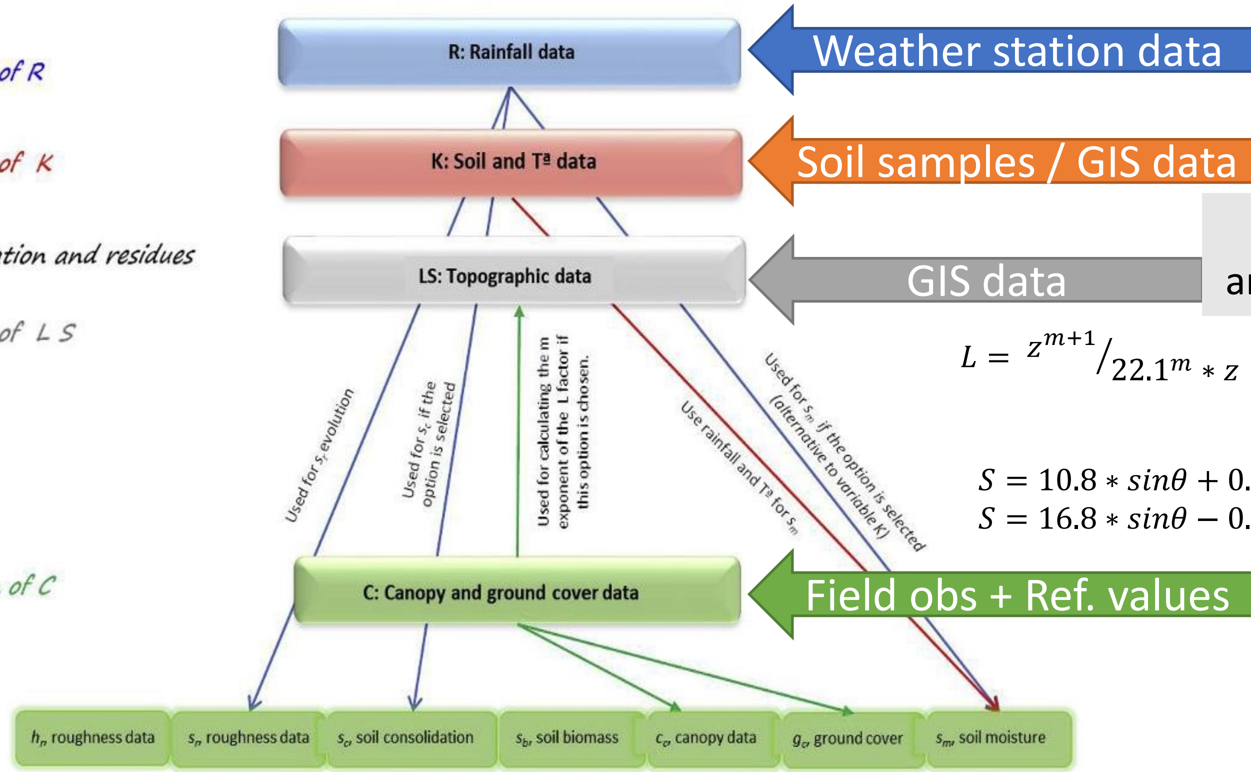
DEM5	Aerial LIDAR acquisition between 2009 and 2011 all over the whole Regional area; 5 m resolution
DEM10	Raster obtained from interpolation of contour lines from historical technical maps ; 10 m resolution
DEM25	Downsampling from the native DEM5 to a 25 m resolution grid

ORUSCAL (Gomez et al., 2020)

ORUSCAL structure



ORUSCAL input data



In ORUSCAL: L and S are computed separately

$$L = z^{m+1}/22.1^m * z$$

z= slope length (m)

m = relevance of rill-interrill erosion

$$S = 10.8 * sin\theta + 0.3 \quad \theta < 9\%$$
$$S = 16.8 * sin\theta - 0.5 \quad \theta \geq 9\%$$

θ= slope

The model is used in the IN-GEST SOIL Project to provide farmers with indications over soil erosion risk in their vineyards

LS factor operator-driven procedure

QGIS

tools

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- Time consuming
- Accuracy affected by the operator

LS factor automated GIS procedure

SAGA GIS tool

LS-factor, field-based

Computational procedure	Moore and Nieber, 1989	MN
	Desmet and Govers, 1996	DG
	Wischmeier and Smith, 1978	WS
Type of slope	Local slope	LOC
	Distant weighted average catchment slope	AVG
Specific catchment area	Contour length as cell size	CS
	Contour length dependent on aspect	AS
	Catchment length	CL
	Effective flow length	FL

For all DEMs available

72 LS estimates

$$LS_{MN} = 0.4 + 1 * \left(A/22.13\right)^{0.4} * \left(sin\theta/0.0896\right)^{1.3}$$

$$L_{DG} = \left((A + d^2)^{m+1} - A^{m+1} / d^{m+2} * 22.13^m * x^m\right)$$

$$S_{DG} = 10.8 * sin\theta + 0.3 \qquad \theta < 9\%$$

$$S_{DG} = 16.8 * sin\theta - 0.5 \qquad \theta \geq 9\%$$

A = upslope contributing area (m^2)
θ = slope
d = raster resolution (m)
m = rill-interrill relevance
x = |sin(Aspect)|+|cos(Aspect)|

$$LS_{WS} = \sqrt{A/22.13} * 65.41 * sin\theta * sin\theta + 4.56 + sin\theta + 0.065 \qquad \theta > 3°$$

$$LS_{WS} = \left(A/22.13\right)^{3\theta^{0.6}} * 65.41 * sin\theta * sin\theta + 4.56 + sin\theta + 0.065 \qquad \theta \leq 3°$$

LS factor automated GIS procedure

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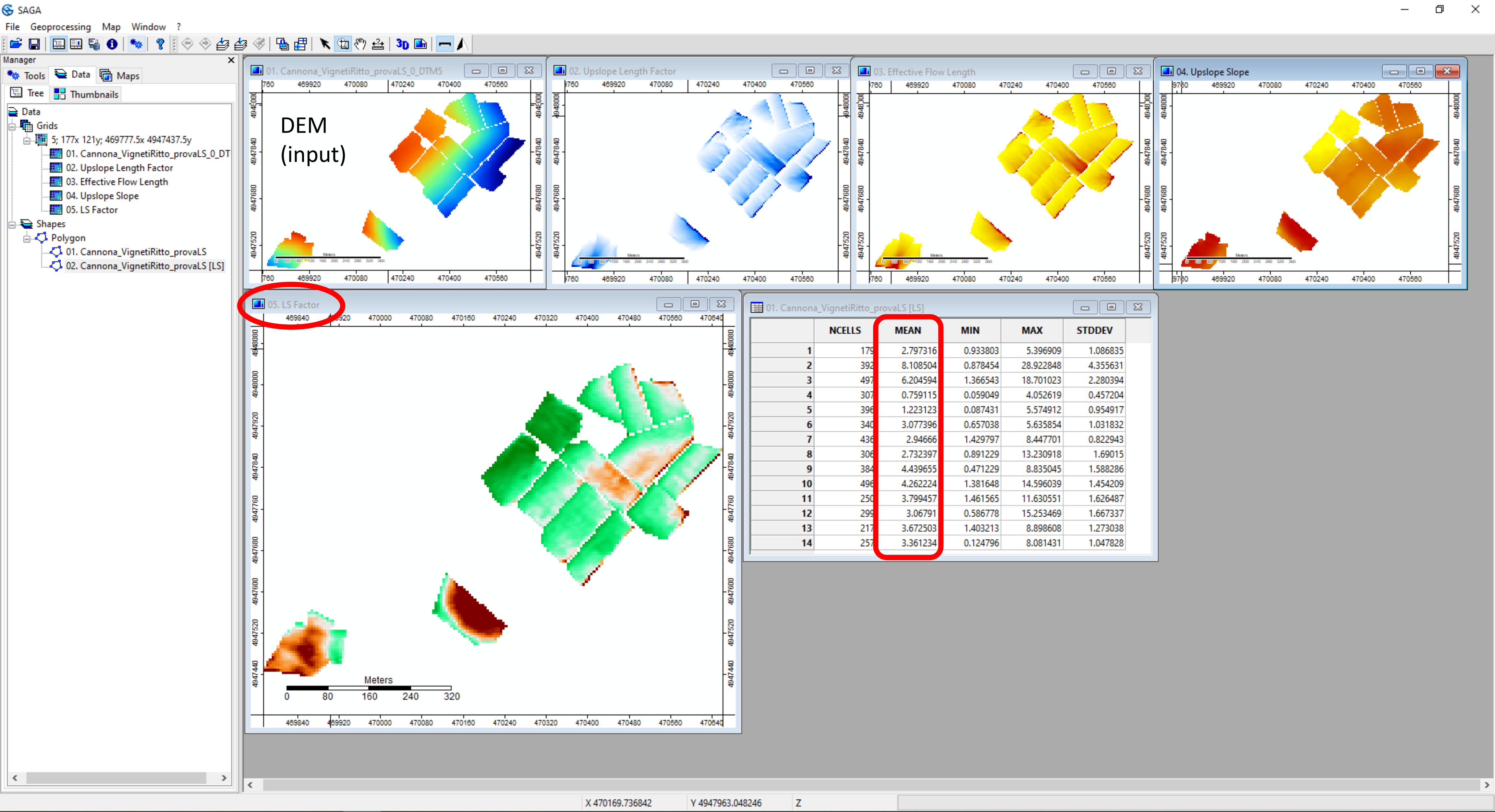
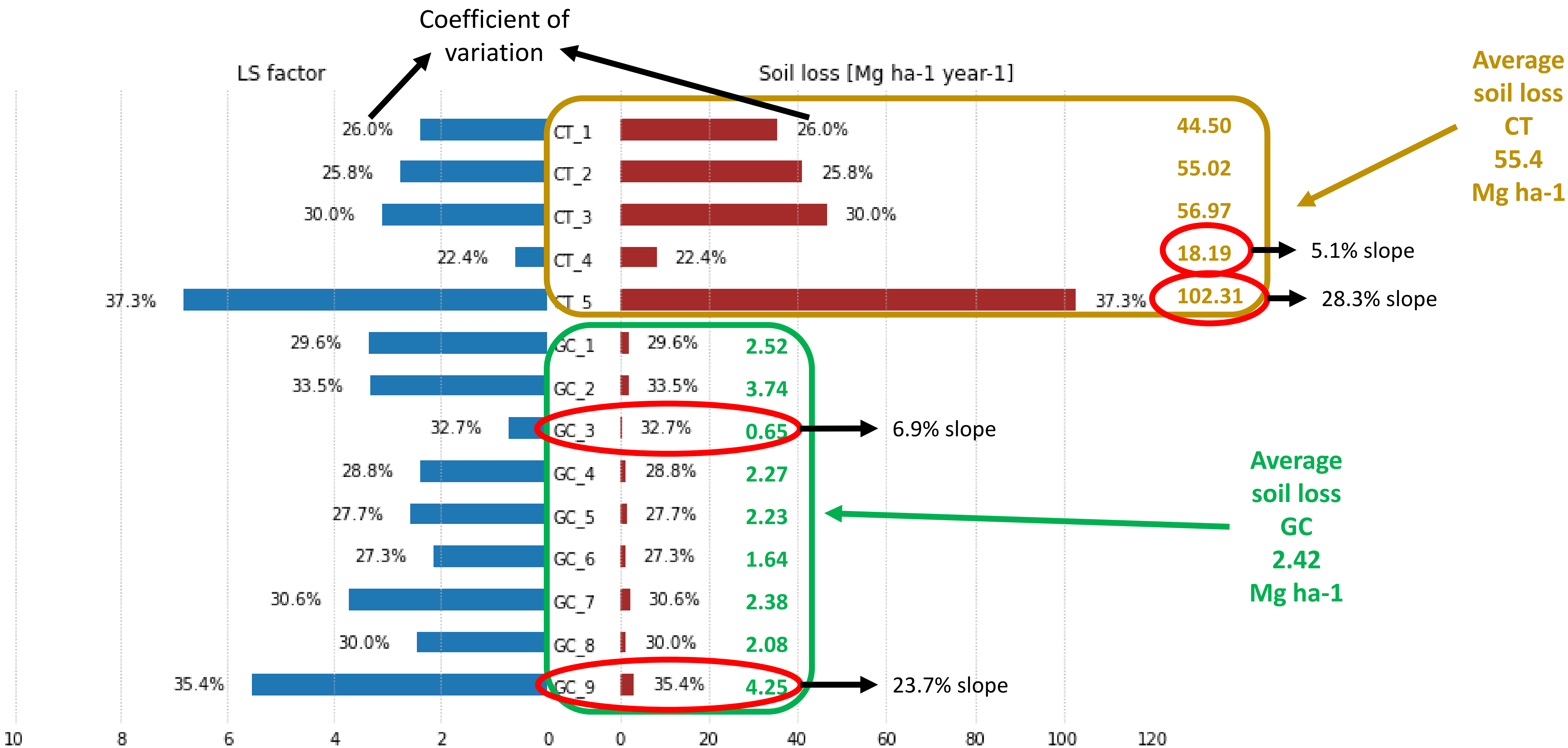


	NCELLS	MEAN	MIN	MAX	STDDEV
1	179	2.797316	0.933803	5.396909	1.086835
2	392	8.108504	0.878454	28.922848	4.355631
3	497	6.204594	1.366543	18.701023	2.280394
4	307	0.759115	0.059049	4.052619	0.457204
5	396	1.223123	0.087431	5.574912	0.954917
6	340	3.077396	0.657038	5.635854	1.031832
7	436	2.94666	1.429797	8.447701	0.822943
8	306	2.732397	0.891229	13.230918	1.69015
9	384	4.439655	0.471229	8.835045	1.588286
10	496	4.262224	1.381648	14.596039	1.454209
11	250	3.799457	1.461565	11.630551	1.626487
12	299	3.06791	0.586778	15.253469	1.667337
13	217	3.672503	1.403213	8.898608	1.273038
14	257	3.361234	0.124796	8.081431	1.047828

Results



Coefficient of variation
LS factor
Soil loss [Mg ha-1 year-1]
CT_1 26.0% 44.50
CT_2 25.8% 55.02
CT_3 30.0% 56.97
CT_4 22.4% 18.19
CT_5 37.3% 102.31
GC_1 29.6% 2.52
GC_2 33.5% 3.74
GC_3 32.7% 0.65
GC_4 28.8% 2.27
GC_5 27.7% 2.23
GC_6 27.3% 1.64
GC_7 30.6% 2.38
GC_8 30.0% 2.08
GC_9 35.4% 4.25
5.1% slope
28.3% slope
6.9% slope
23.7% slope
Average soil loss CT 55.4 Mg ha-1
Average soil loss GC 2.42 Mg ha-1
10 8 6 4 2 0
0 20 40 60 80 100 120

Moore & Nieber, 1989 | Desmet & Govers, 1996 | Wischmeier & Smith, 1978

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LS factor computation - Slope type LOCAL

Similar results can also be seen in the final soil loss estimation, although differences between different input combinations tend to be less evident (R^2>0.9)

Moore & Nieber, 1989 | Desmet & Govers, 1996 | Wischmeier & Smith, 1978

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LS factor computation - Slope type AVERAGE

- Permanent grass-cover can decrease soil erosion risks even in sloping areas
- Down-sampling DEM affects LS assessment
- DEM resolution is fundamental…
- … but so are the algorithm that we choose to adopt
- DEM resolution may be artificially improved by resampling raster data

The right combination of open-source data and computational procedures can replace time-consuming measuring procedures to assess parameters required by RUSLE/ORUSCAL to compute LS

THANK YOU FOR THE ATTENTION

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IN-GEST SOIL
Innovazione nella gestione dei suoli viticoli attraverso l'adozione di buone pratiche e strumenti di supporto alle attività di campo

REGIONE PIEMONTE

FEASR Fondo europeo agricolo per lo sviluppo rurale: l'Europa investe nelle zone rurali

PSR

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