

G2

erosion model

a short user guide



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December 2017

History

G2 model has three modules: *G2/los* (for soil loss), *G2sed* (for sediment yield) and *G2met* (for heavy metals)

It was introduced in 2010 (*G2/los*) in the framework of geoland2 project (GMES, now COPERNICUS); later, *G2sed* and *G2met* were accomplished

It adopted equations from R-USLE (Wischmeier & Smith), EPM (Gavrilovic), and PERI (Hakanson)

It gets input from standard big geodatabases (BIOPAR, CORINE, ESDB, LUCAS-Soil, EuroDEM, Sentinel-2), etc.

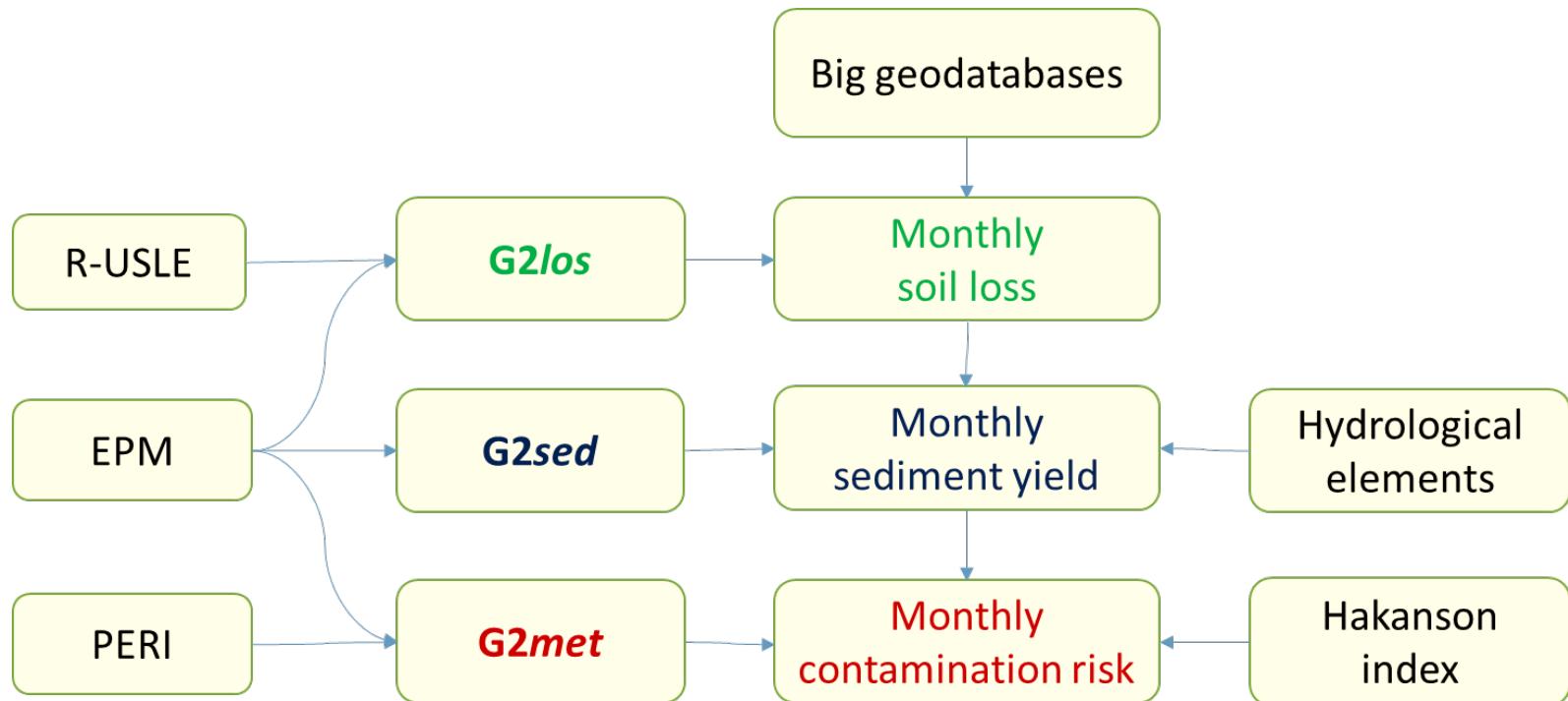
Characteristics

Erosion type	Sheet – interril
Erosion features	Soil loss, sediment yield, heavy metal risk
Erosion processes	Splash, surface runoff
Spatial scale	Minimum mapping unit: 1 ha
Temporal scale	Month: long term; averaged
Mathematical basis	Empirical: R-USLE, EPM, PERI
Type of assessment	Quantitative (t/ha)

Modules

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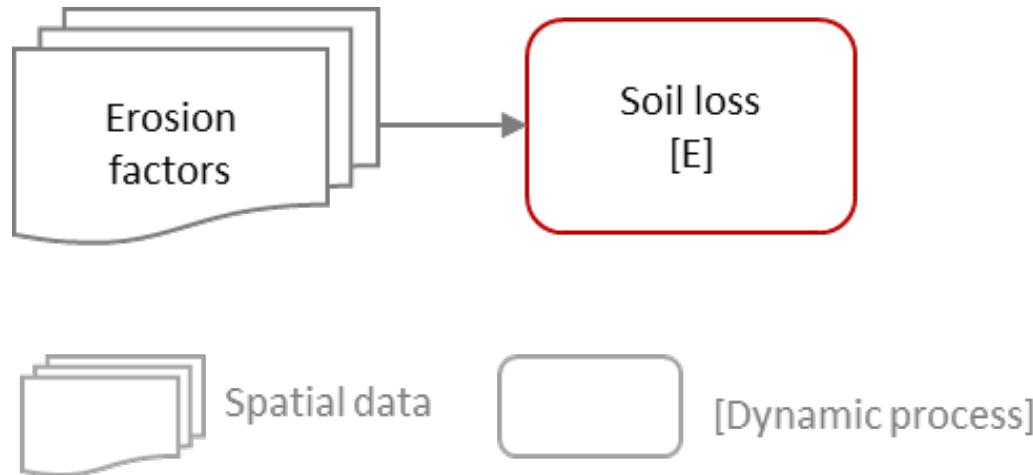


G2/los

Overview

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$$E_m = (R_m/V_m) * S * (T/L)$$

E_m : soil loss for month m ($t \text{ ha}^{-1}$)

R_m : rainfall erosivity of month m ($\text{MJ mm ha}^{-1} \text{ h}^{-1}$)

V_m : vegetation retention for month m (dimensionless)

S : soil erodibility ($t \text{ ha h MJ}^{-1} \text{ ha}^{-1} \text{ mm}^{-1}$)

T : terrain influence (dimensionless)

L : landscape effect (dimensionless)

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Alternatives

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Erosion factors	Ready-to-use layers	Use of equations	Use of matrices
R	Globe	Globe	N/A
V	N/A		Globe
S	EU only	Globe	Globe
T	EU only	Globe	N/A
L	N/A	Globe	N/A

Explanation: for study areas inside the EU territories, R, S, and T ready-layers may be taken, only V and L layers need preparation by the users; whereas, for study areas outside EU territories only R ready-layers are available, while V, S, T, and L layers need preparation (for S layer, there are two alternatives depending on data availability)

	Input factors	Processes	Time step
Use of equations	v_r i_r	Calculation of $R(v_r, i_r)$ at meteorological stations (where rain intensity data are available) Interpolation of R values of stations, with ready-to-use rainfall surfaces	5-60 min
Ready-to-use R-layers (per month)	Meteorological stations (i_r) http://www.worldclim.org/ (v_r)	EU: http://esdac.jrc.ec.europa.eu/content/rainfall-erosivity-european-union-and-switzerland Out of EU: http://esdac.jrc.ec.europa.eu/content/global-rainfall-erosivity	

$$R_m = \frac{1}{n} \sum_{i=1}^n \left\{ \sum_{j=1}^k (EI_{30})_j \right\}_i$$

$$EI_{30} = \left(\sum_{r=1}^t e_r v_r \right) \cdot I_{30}$$

$$e_r = 0.29 [1 - 0.72 \exp(-0.05 i_r)]$$

R_m : rainfall erosivity for month m ($\text{MJ mm ha}^{-1} \text{h}^{-1}$)

i: years recorded

j: erosive events during month m

I_{30} : the maximum rainfall intensity of the event during a period of 30 minutes of event j (mm h^{-1})

e_r : rainfall energy per surface unit and per rainfall volume of a predefined time interval ($\text{MJ ha}^{-1} \text{mm}^{-1}$)

v_r : the rainfall volume during the predefined time interval (mm)

r: predefined time intervals during the rainfall event

i_r : rainfall intensity during the predefined time interval r (mm h^{-1})

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V, data/processes

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Input factors	Processes	Data sources	Scale	Time step Updates
FC	Normalized value [0,1]; > 4-year sequence Downscaling with high resolution imagery	EU: BIOPAR/PROBA-V Globe: BIOPAR/SPOT-VGT Globe: Sentinel-2	PROBA-V: 333 m SPOT-VGT: >1 km 10 m	10 days
	http://land.copernicus.eu/global/products https://scihub.copernicus.eu/dhus/#/home			
LU	Conversion of LC class to LU value (matrix)	EU: CORINE	250 m/25 ha	EU: 6 years
	http://land.copernicus.eu/pan-european/corine-land-cover			
imp	Normalized value [0,1]	EU: Copernicus HRL	20 m	EU: 3 years
	http://land.copernicus.eu/pan-european/high-resolution-layers/imperviousness/view			

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V equation

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$$V_{mj} = (1 - imp)^{-1} \cdot e^{(LU_j \cdot FC_m)}$$

V_{mj} : V-factor for month m and land cover/use j, in range $[1, +\infty)$
(dimensionless)

imp : imperviousness degree corresponding to 0 to 100% of soil sealing,
in range $[0,1]$ (dimensionless)

LU_j : empirical parameter for land use j, in range $[1, 10]$ (matrix), with
lower values corresponding to intensive management or unprotected
land uses and higher values corresponding to better management
conditions

FC_m : Fractional vegetation cover for month m, in range $[0,1]$
(dimensionless)

G2los V, matrix

j (CORINE codes)	LU	j (CORINE codes)	LU
111	10	311	10
112	10	312	10
121	10	313	10
122	10	321	8
123	10	322	7
124	10	323	9
131	1	324	7
132	1	331	5
133	1	332	7
141	10	333	7
142	10	334	7
211	5.5	411	1
212	1	421	1
213	1	422	1
221	3.5	511	1
222	4.5	512	1
223	4.5	521	1
231	9.5	522	1
241	5.5	523	1
242	7.0		
243	6.5		

For CORINE codes, refer to:
<http://land.copernicus.eu/pan-european/corine-land-cover>

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S, data/processes

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	Input factors	Processes	Scale
Use of equation	M OM S P	Calculation of S at sampled points Interpolation of S point values (Kriging recommended)	
		EU: http://esdac.jrc.ec.europa.eu/content/european-soil-database-v20-vector-and-attribute-data	
Use of matrix	M OM	Conversion of texture class layer to M layer (matrix) Effect of organic matter layer using corrective equation	
		EU: http://esdac.jrc.ec.europa.eu/content/european-soil-database-v20-vector-and-attribute-data	
Ready-to-use S-layer		EU: http://esdac.jrc.ec.europa.eu/themes/soil-erodibility-europe	500 m

$$S=0.1317 * \{ [2.1 * 10^{-4} * M^{1.14} * (12 - OM) + 3.25 * (s - 2) + 2.5 * (p - 3)] / 100 \}$$

S: soil erodibility ($t \text{ ha h ha}^{-1} \text{ MJ}^{-1} \text{ mm}^{-1}$)

M: textural factor defined as percentage of silt plus very fine sand fraction content (0.002-0.1mm) multiplied by the factor: 100 - clay fraction

OM: organic matter content in per cent (%)

s: soil structure class (s=1: very fine granular, s=2: fine granular, s=3: medium or coarse granular, s=4: blocky, platy or massive)

p permeability class (p=1: very rapid, ..., p=6: very slow)

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S, matrix

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Code	Description	% clay	% silt	% sand	S_o
0	No information	-	-	-	
9	No texture (histosols, ...)	-	-	-	
1	Coarse (clay < 18 % and sand > 65 %)	9	8	83	0.0115
2	Medium (18% < clay < 35% and sand > 15%, or clay < 18% and 15% < sand < 65%)	27	15	58	0.0311
3	Medium fine (clay < 35 % and sand < 15 %)	18	74	8	0.0438
4	Fine (35 % < clay < 60 %)	48	48	4	0.0339
5	Very fine (clay > 60 %)	80	20	0	0.0170
$S_c = S_o * e^{(-0.1013 \text{ OM})}$		S_c : S-value corrected for OM content, S_o : original S-value (before correction), OM: organic matter content (%)			

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T, data/processes

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	Input factors	Processes	Scale
Use of equation	A_s b	D8 method Slope in %	25-30 m
		https://asterweb.jpl.nasa.gov/gdem.asp https://www.eea.europa.eu/data-and-maps/data/copernicus-land-monitoring-service-eu-dem	
Ready-to-use T-layer	EU: http://esdac.jrc.ec.europa.eu/content/ls-factor-slope-length-and-steepness-factor-eu		25 m

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T, equation

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$$T = \left(\frac{A_s}{22.13} \right)^{0.4} \left(\frac{b}{0.0896} \right)^{1.3}$$

T: terrain influence (dimensionless, ≥ 0)

A_s : unit contributing area (or flow accumulation), defined as the surface upstream flowing into a specific unit surface (dimensionless, >0)

b: slope gradient at the unit surface (rad)

The above exponents are typical for low susceptibility to rill erosion

G2/los

L, data/processes

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Input factors	Processes	Data sources	Scale	Time step Updates
S_b	3x3 Sobel filtering	Sentinel-2	10 m in NIR	5-10 days
https://scihub.copernicus.eu/dhus/#/home				

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L, equation

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$$L = 1 + \sqrt{\frac{S_f}{DN_{\max}}}$$

L: landscape effect in range [1,2] (dimensionless)

S_f: Sobel filter value in range [0, DN_{max}] (dimensionless)

DN_{max}: theoretic maximum digital number of the image (e.g. 255 for 8-bit recording systems) (dimensionless)

G2los

Mathematical relations

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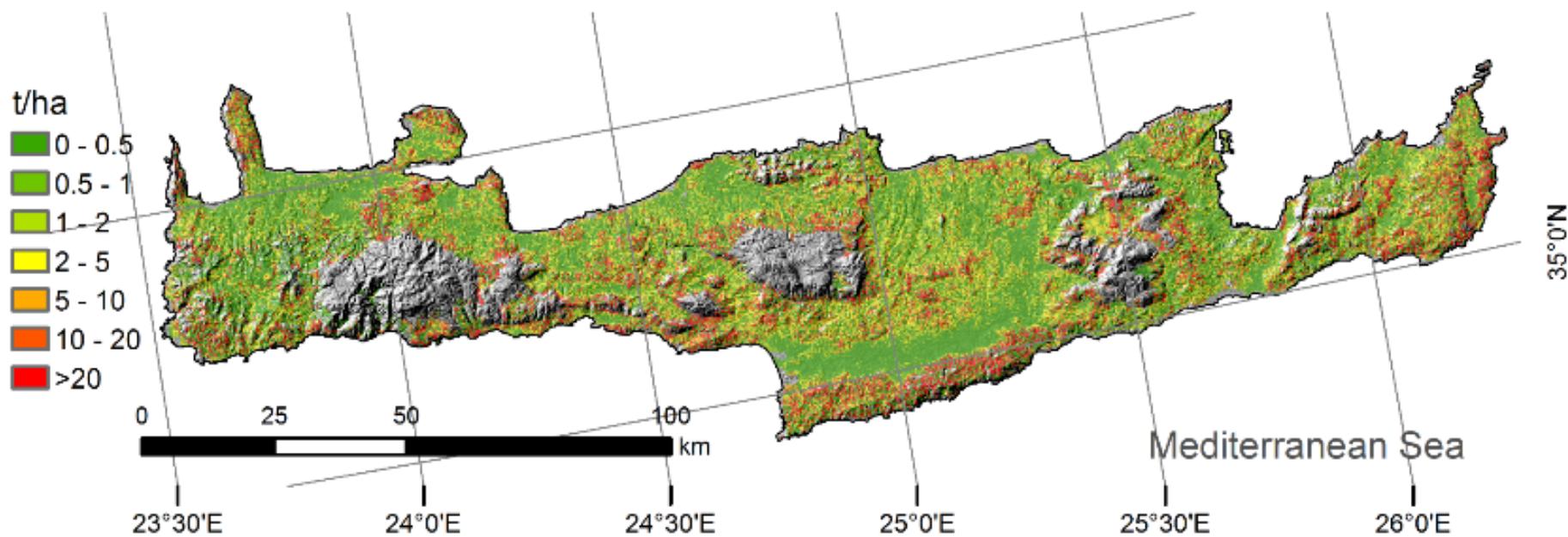
Factor	Role	Character	Units	Range	Dimensionality
					P: Power L: Length M: Mass
R	Erosive	Dynamic	MJ mm ha ⁻¹ h ⁻¹	[0,+∞)	[P][L ⁻¹]
V	Protective	Dynamic	-	[1,+∞)	0
S	Erosive	Static	t ha h MJ ⁻¹ ha ⁻¹ mm ⁻¹	(0,0.1)	[M][P ⁻¹][L ⁻¹]
T	Erosive	Static	-	[0,20]	0
L	Protective	Static	-	[1,2]	0
E	Erosion	Dynamic	t ha ⁻¹	[0,+∞)	[M][L ⁻²]

G2/los

Example, Soil loss map

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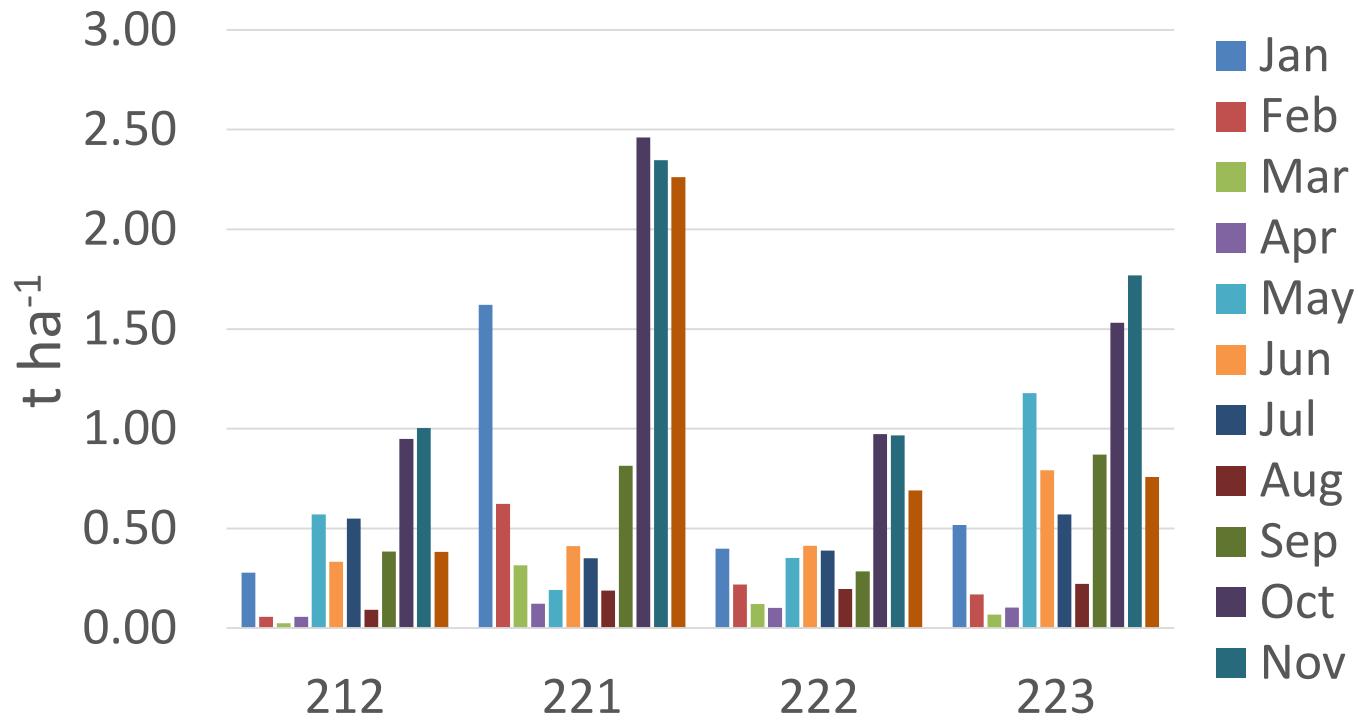
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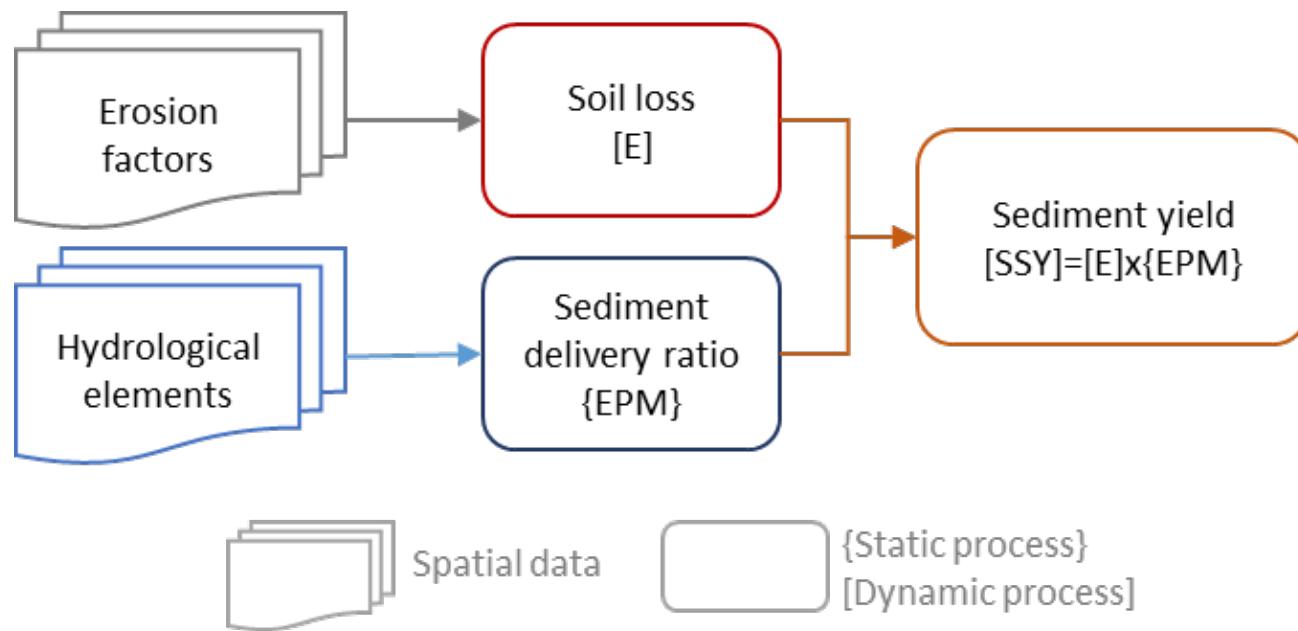
Example, Land use stats

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G2sed Overview

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G2sed Equations

$$SSY_m = SDR_w \cdot E_m$$

$$SDR_w = \frac{\sqrt{P \cdot Z} \cdot (L_p + L_s)}{(L_p + 10) \cdot A}$$

SSY_m : area-specific sediment yield
(sediment yield rate) during month m (t ha⁻¹)

SDR_w : sediment delivery ratio of watershed w (sub-basins), in range [0,1], dimensionless)

E_m : soil loss rate for month m (t ha⁻¹)

P: perimeter (km)

Z: difference of minimum from mean altitude of w (km)

L_p : total length of the primary stream segments of w (km)

L_s : total length of the secondary stream segments of w (km)

A: projective surface of w (km²).

G2sed

Processes

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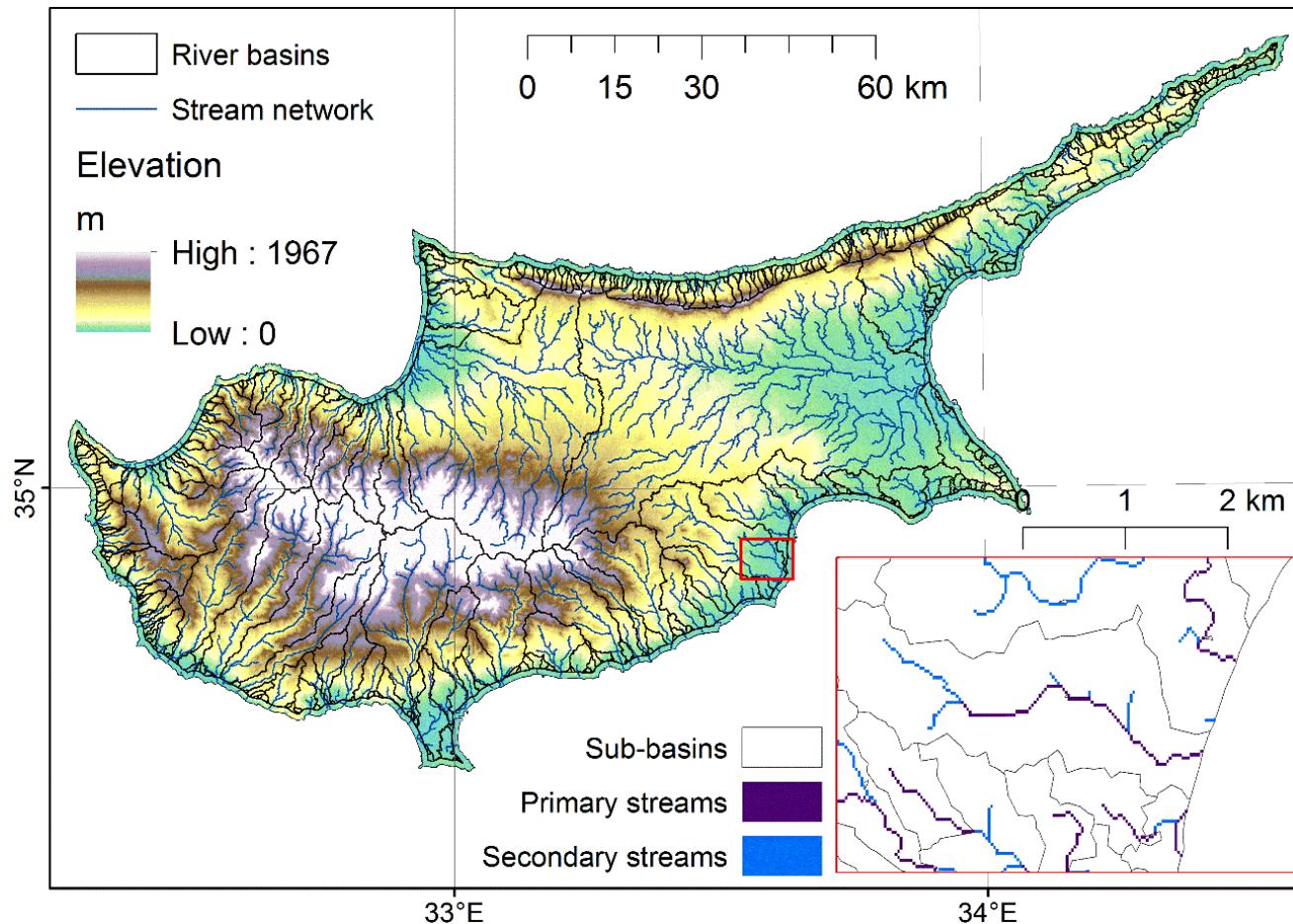
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	Input factors	Processes	Scale
Use of equations	E_m P Z L_p L_s A	$G2los (E_m)$ D8 method (watershed delineation) Strahler method (stream network) Geometric operations (P, A, L_p, L_s) Zonal statistics (Z)	1 ha (DEM: 25-30 m; E_m : 100 m)
Methodological steps for SDR			
<ol style="list-style-type: none">1. Calculation of SDR at the river basin scale (SDR_b)2. Calculation of SDR at the finest possible watershed scale (SDR_{fw})3. Arithmetical adjustment of SDR_{fw} (multiplication with the ratio SDR_b/SDR_{fw})			

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Example, Hydrology elements

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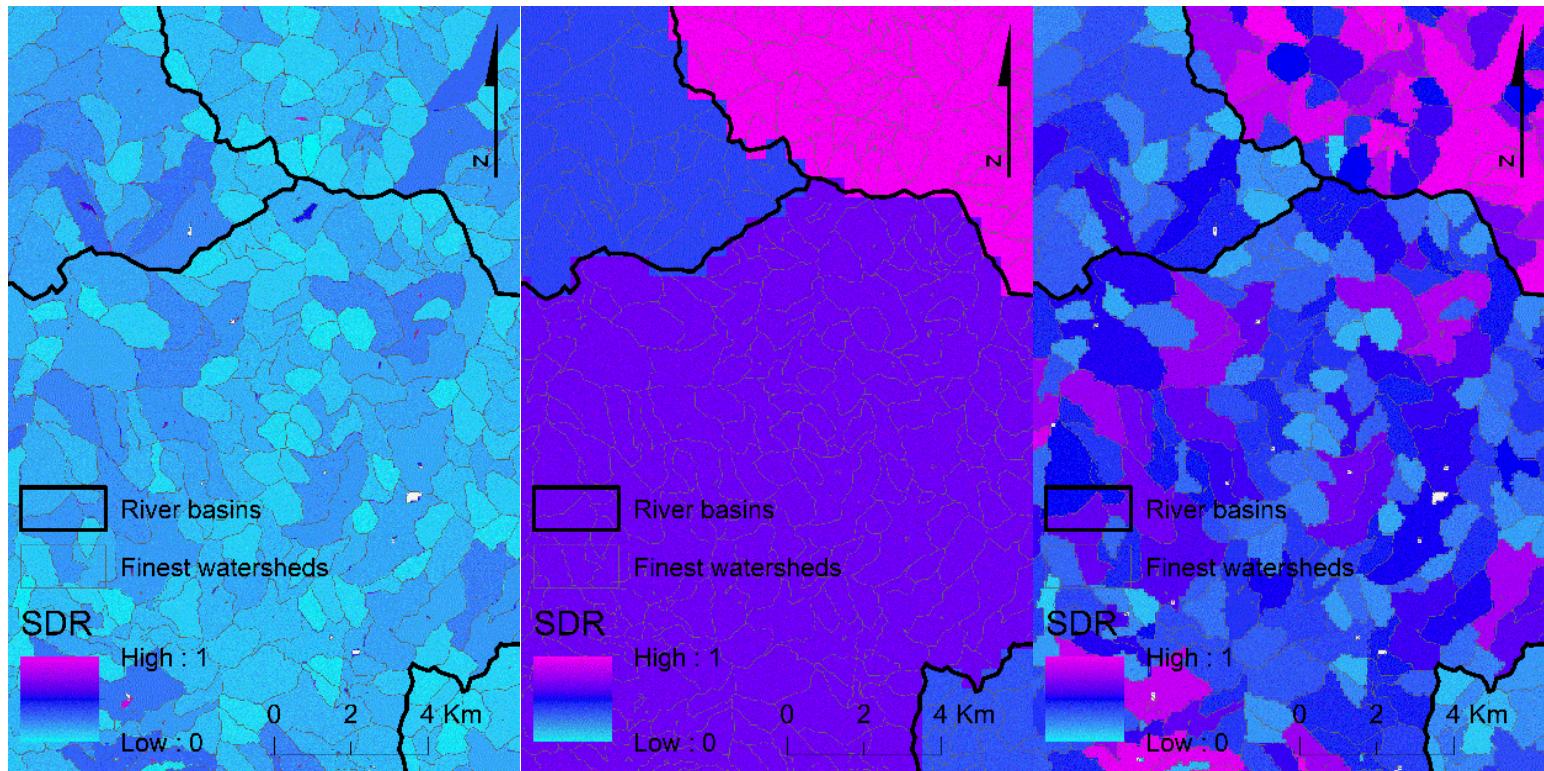


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Example, SDR adjustment

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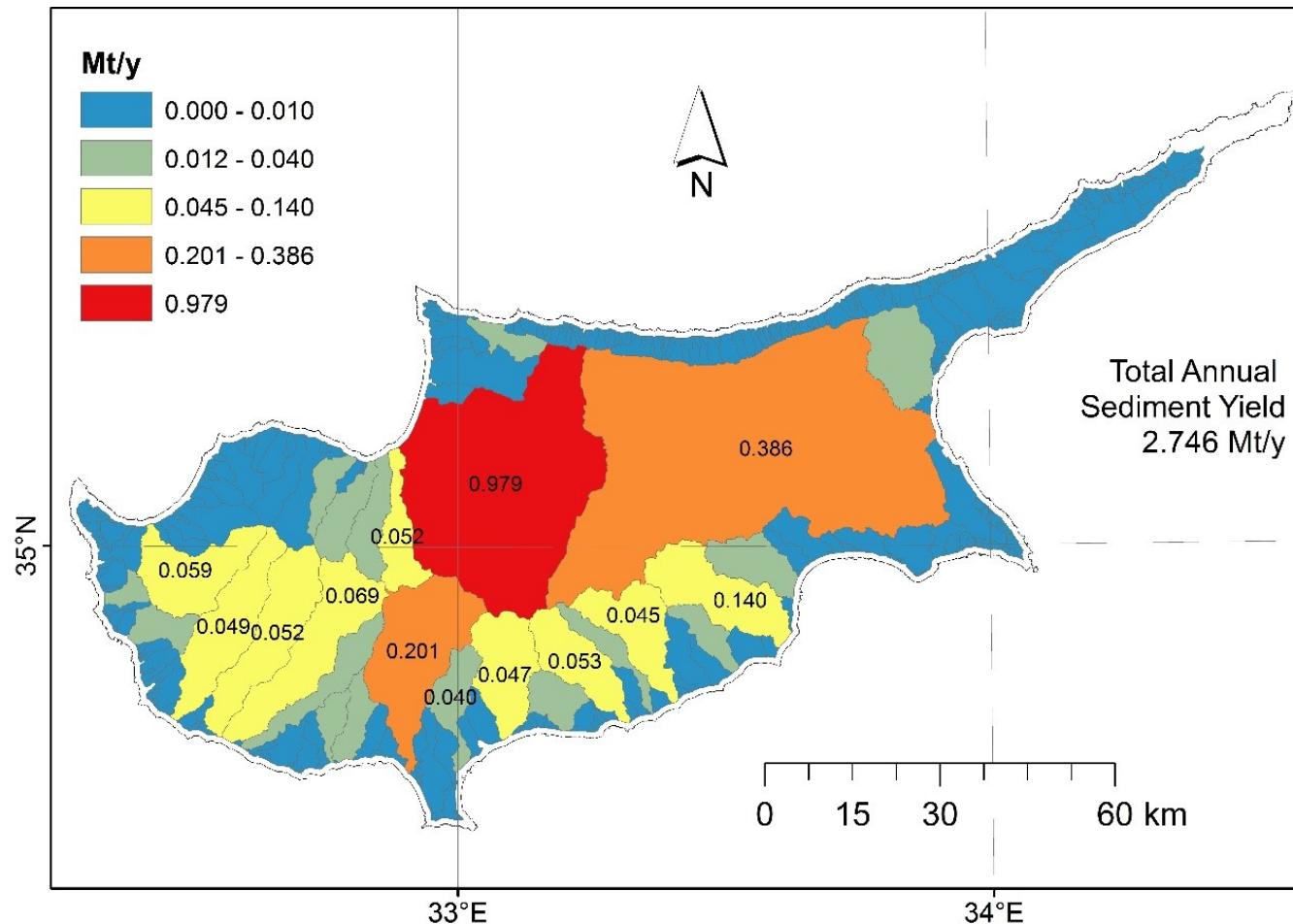
erosion model



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Example, SSY at basins

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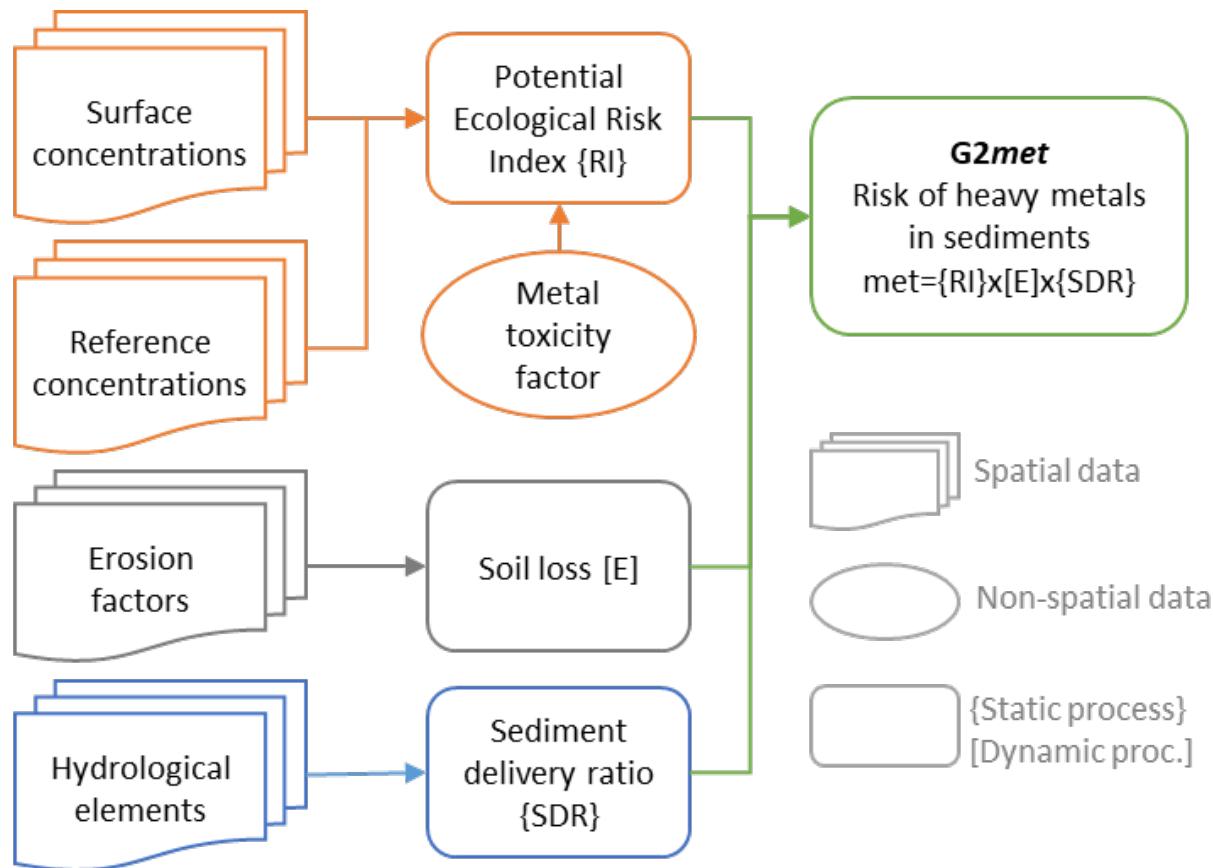


G2met

Overview

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G2met

Equations

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$$met_m = RI * SSY_m$$

$$RI = \sum (E_r^i)$$

$$E_r^i = T_f^i * C_f^i$$

$$C_f^i = \frac{C_s^i}{C_r^i}$$

met_m : risk index for month m

SSY_m : area-specific sediment yield for month m on a predefined scale (watershed or basin)

RI: the potential ecological risk index, describing a comprehensive value of multiple pollutants

E_r^i : the specific metal potential ecological risk factor

T_f^i : the biological toxicity factor for a single metal, which is used to reflect the toxic levels of heavy metals and the water sensitive to the metal contamination

C_f^i : the contamination factor of metal I

C_s^i : the measured concentration of the metal i in the sample

C_r^i : the reference concentration of the metal in the sediments

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Processes

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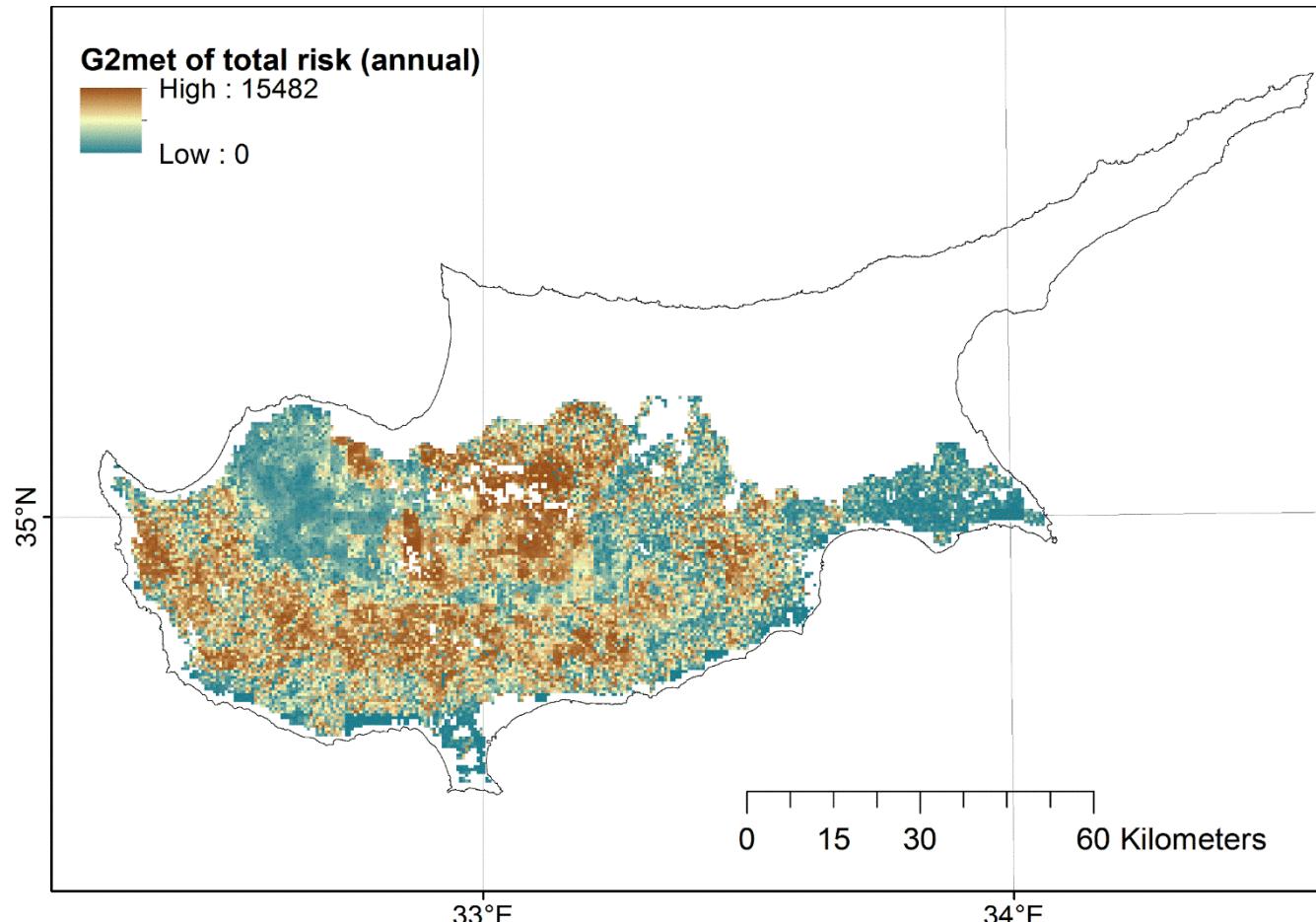
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	Input factors	Processes	Scale
Use of equations	SSY_m C_s^i C_r^i T_f^i	$G2sed (SSY_m)$ Hakanson method (C_s^i, C_r^i, T_f^i)	1 ha (SSY_m)

G2met

Example, met-index surface

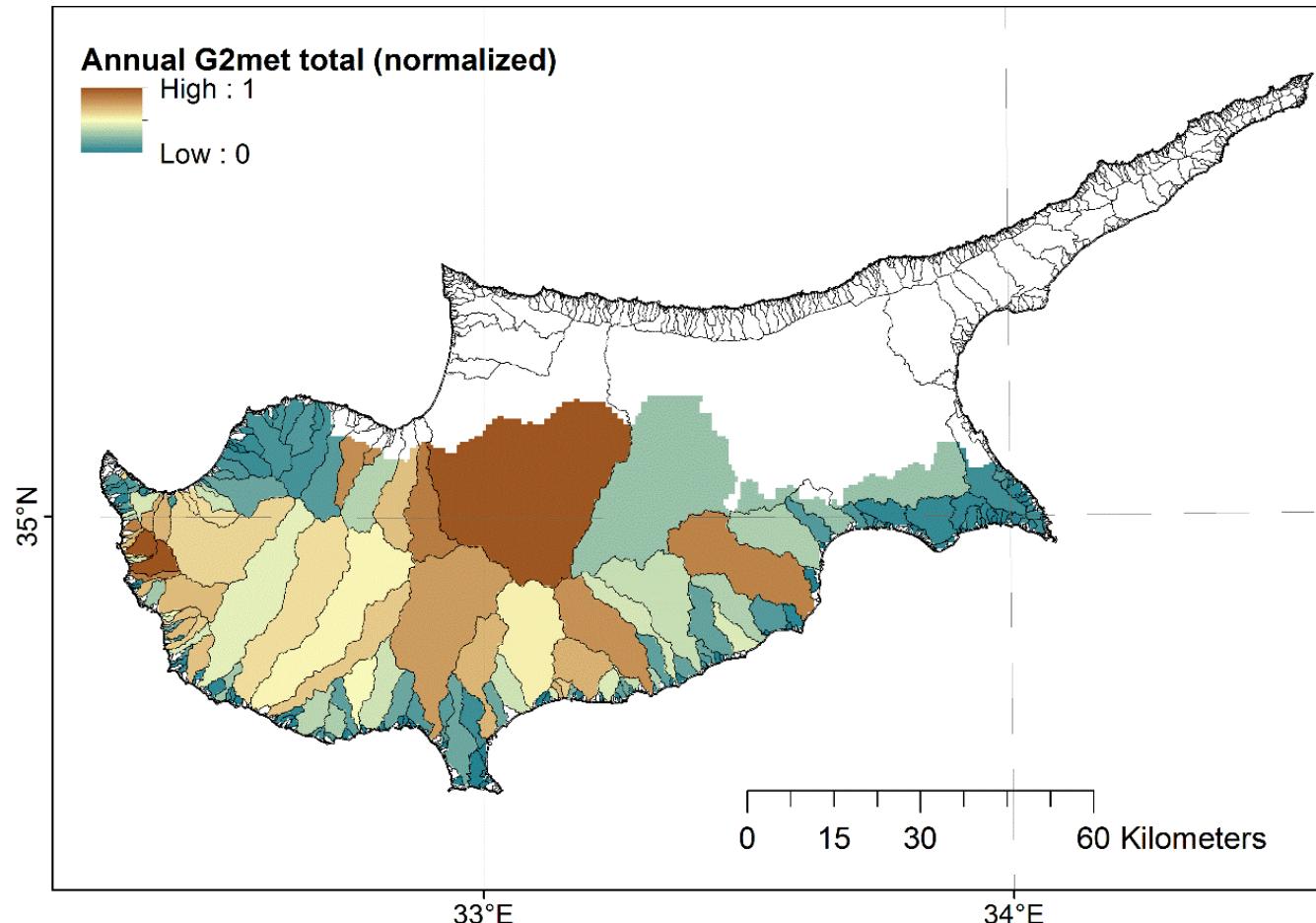
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G2met

Example, met-index basins

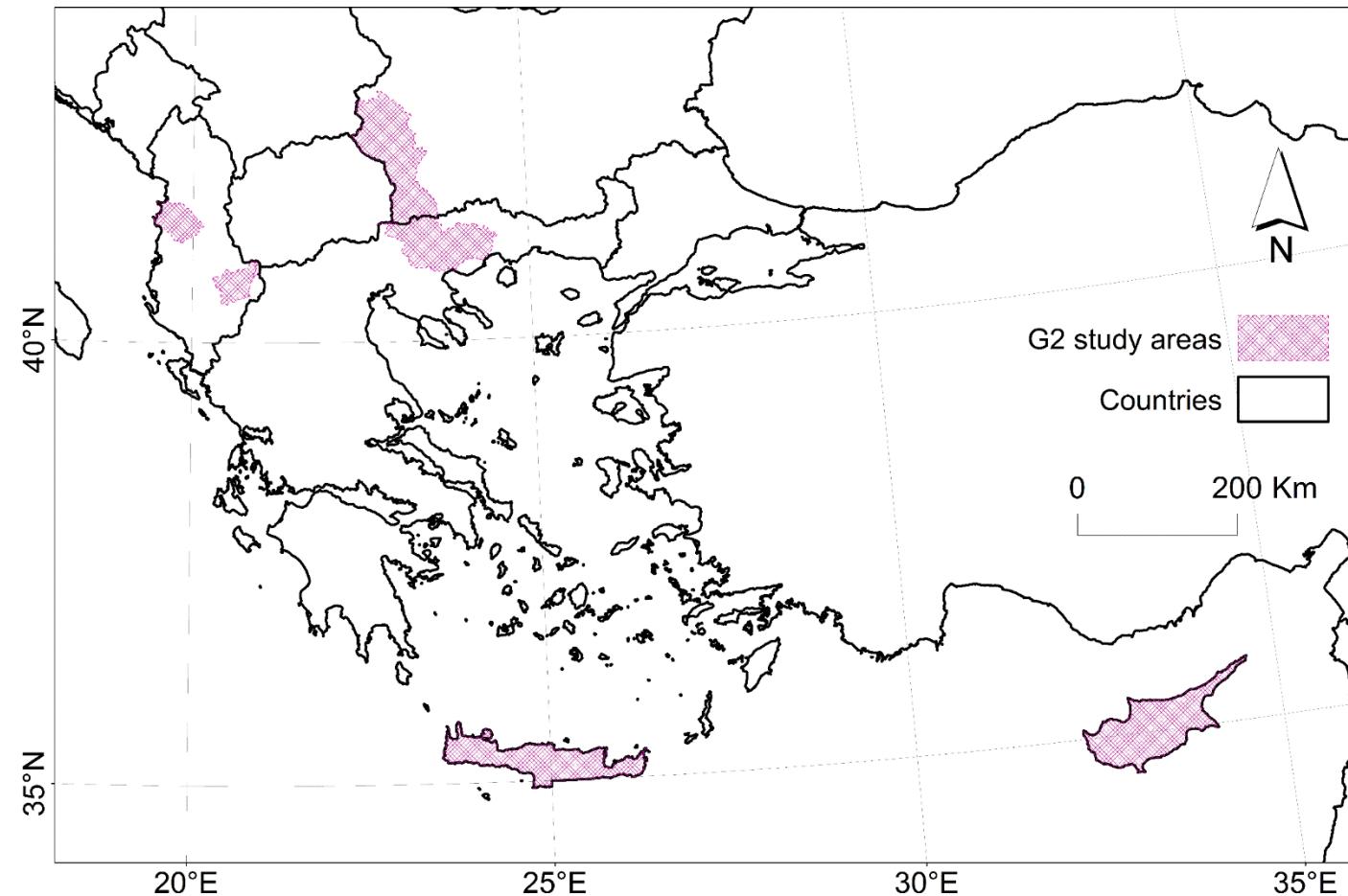
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Case-studies



Main reference

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Karydas, C.G. and Panagos, P. The G2 erosion model: An algorithm for month-time step assessments, *Environmental Research*, Volume 161, February 2018, Pages 256-267 (ISSN 0013-9351)

Open access online: <https://doi.org/10.1016/j.envres.2017.11.010>



The G2 erosion model: An algorithm for month-time step assessments

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More info and data: <http://esdac.jrc.ec.europa.eu/themes/g2-model>

Further reading

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