Modification of some parameters in EPM and RUSLE methodology

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Project "Achieving Biodiversity Conservation through Creation and Effective Management of Protected Areas and Mainstreaming Biodiversity into Land Use Planning"

Project component 3.1.1.1.: "Preparation of soil erosion and drought vulnerability map, and identification of high-risk zones and their impact to biodiversity" 2019-2021

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Project tasks

1 - Erosion modelling using EPM - Erosion Potential Method
2 - Erosion modelling using RUSLE – Revised Universal soil loss equation
3- Aridity modelling
4 - Drought vulnerability modelling
5 - Delineation of Region vulnerable to desertification
6 – Identification High risk zones and impact on the biodiversity

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Erosion intensity maps using RUSLE and EPM

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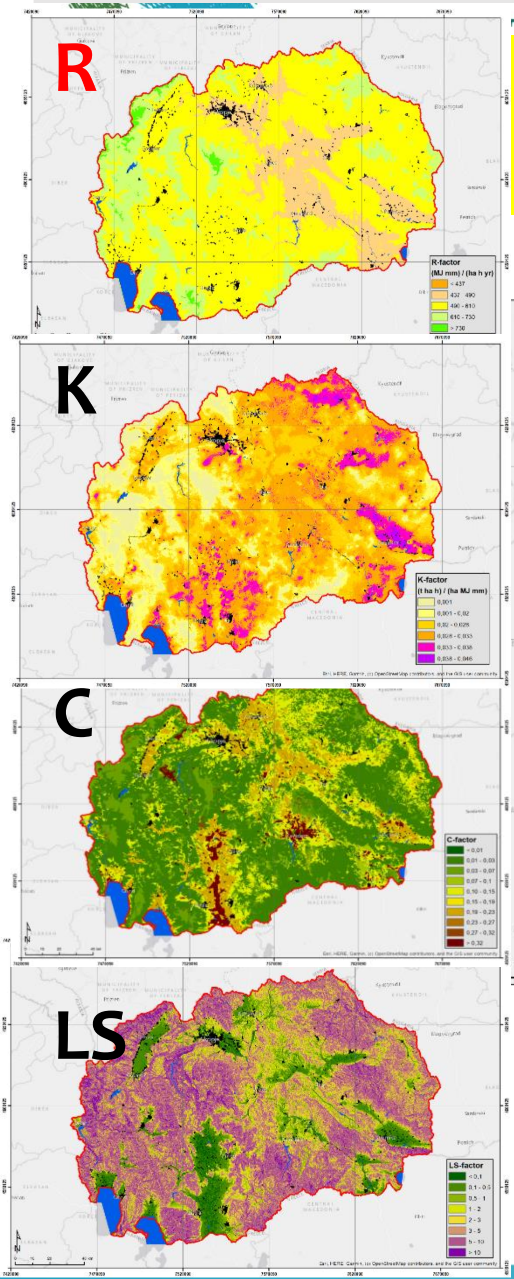
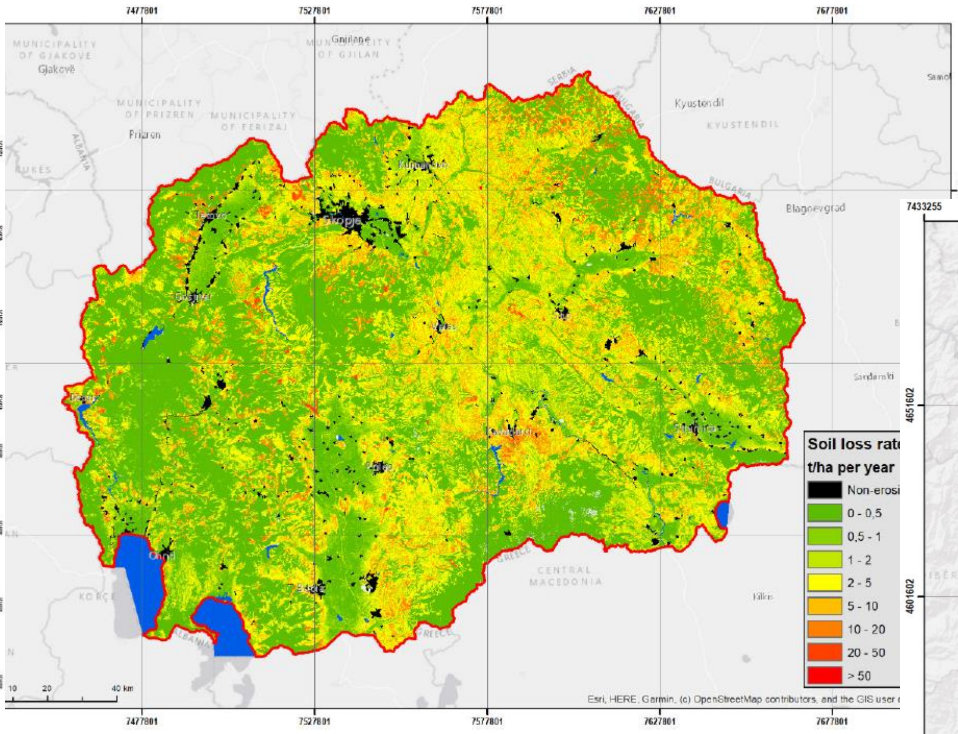
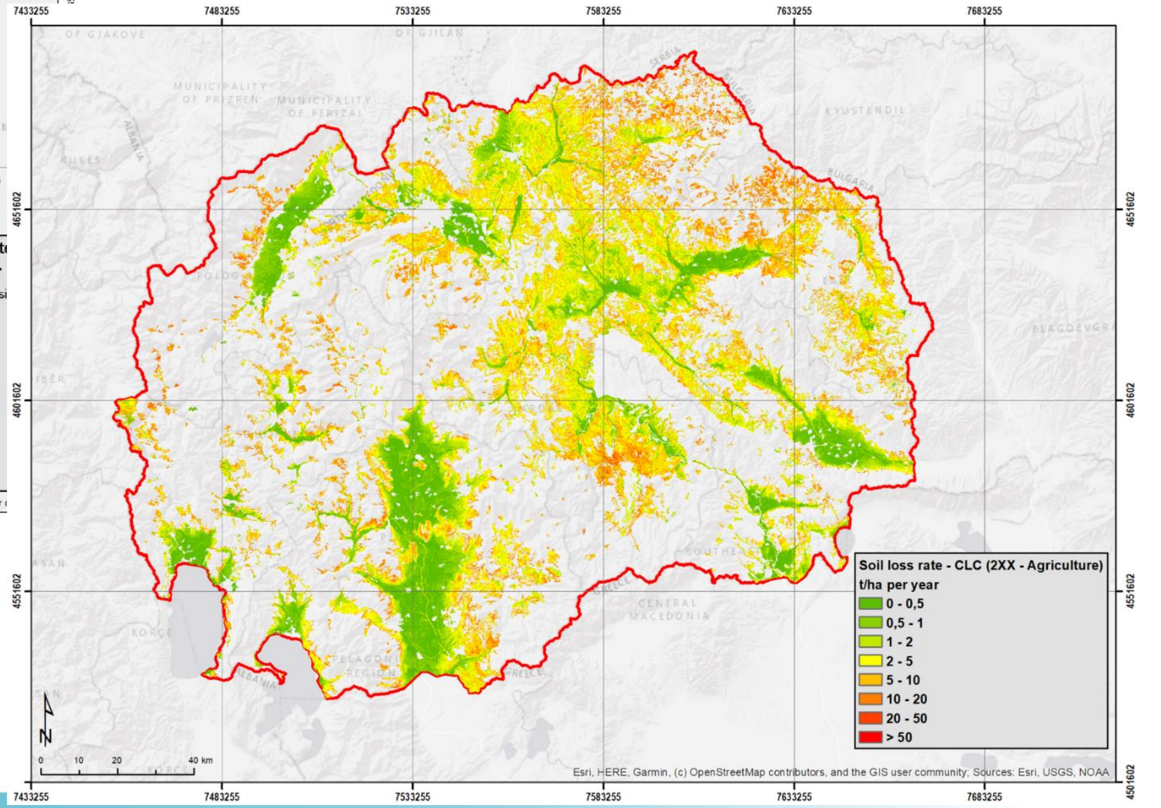
RUSLE modelling $E = R \times K \times C \times LS \times P$ [t / ha]

- Map was developed following the methodology/approach used during preparation of EU erosion map (Panagos et al, JRC, 2015).







R factor – rainfall erosivity [MJ mm ha^{-1} h^{-1} yr^{-1})\]

$$R = \frac{1}{n}\sum_{j=1}^{n}\sum_{k=1}^{mj}(EI30)k$$

- The only parameter that was problematic was R-factor (rainfall erosivity factor) for whose calculation is necessary long-term data on rainfall intensity on various pluviometric stations.

- This type of data doesn't exist in the country.

- **How to solve the problem ?**

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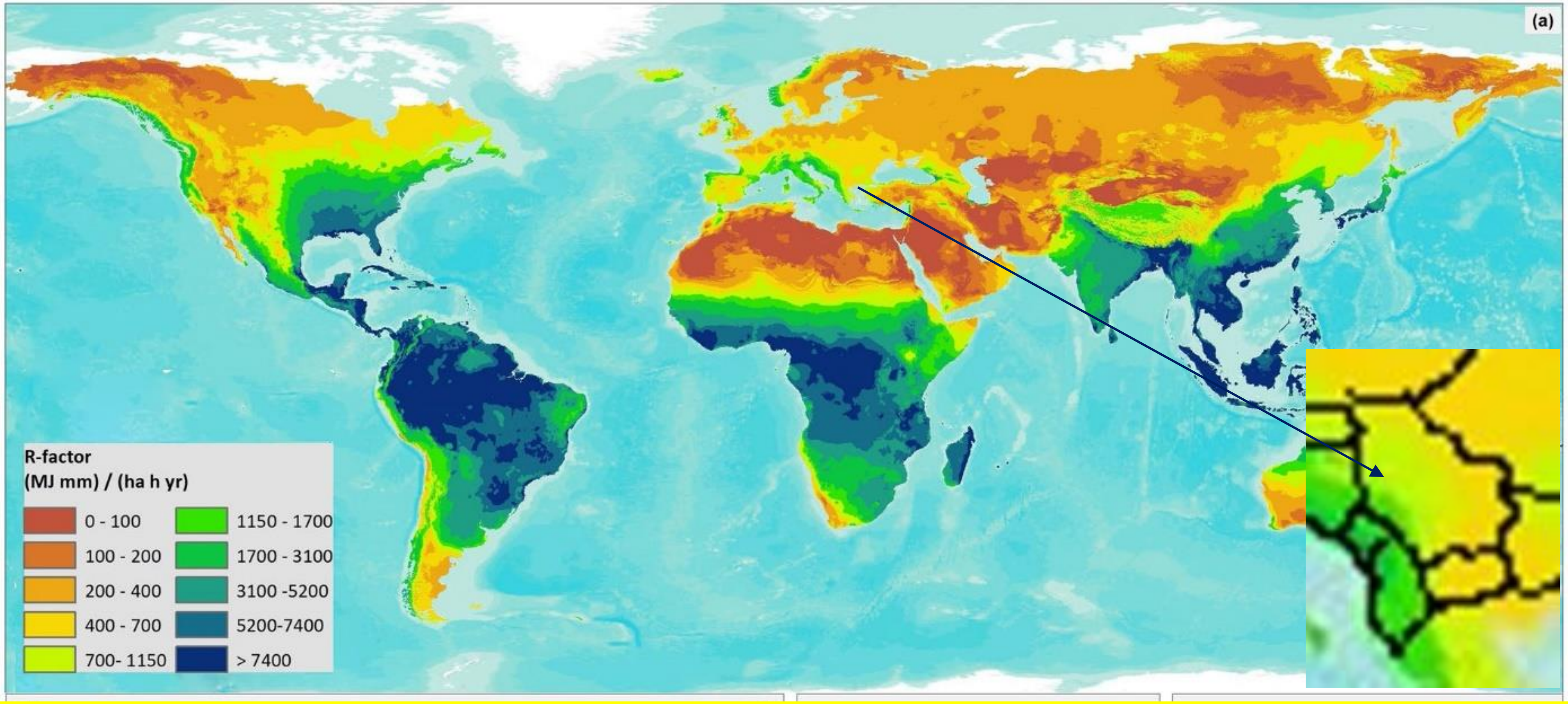
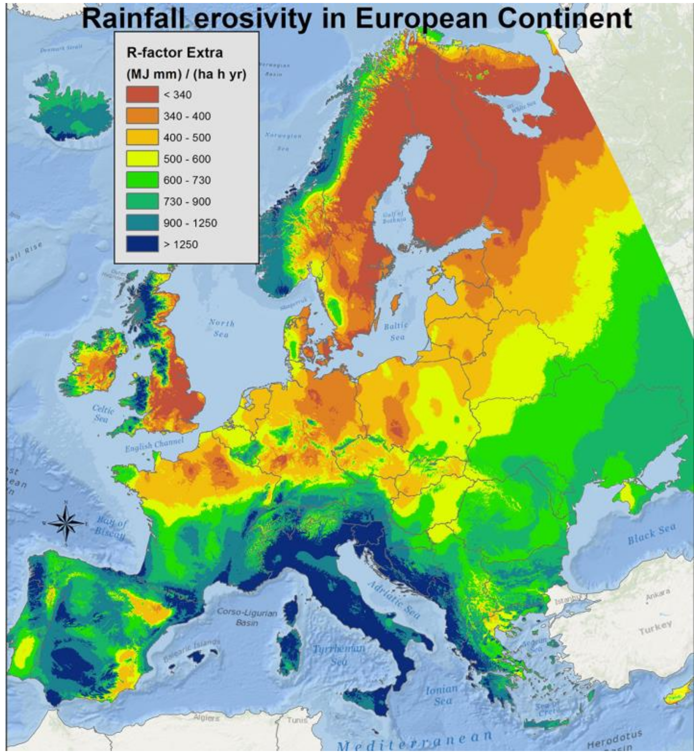
Global R - data (Panagos et al)





- The accuracy of the model is 30 arc.sec and (~1 km) based on the Gaussian regression model, The Balkan countries for which there is data for calculating the R-factor are: GRE, BG, ROM, HU, CR and Slovenia, while there is no relevant data for North Macedonia, Serbia, Montenegro, BiH and Albania

- Various authors faced with the same problem, tried to solve this based on a annual sum of precipitations.
- More then 20 various equations developed in various regions in the world, were tested and more of them resulted in very high values (even more then 4000) because of regional circumstances.

Author	Year	Equation	Region
Bois	1978	$R = 2.5 P^2 / 100 (0.073^P + 0.73)$	
Mikhailova, Bryant, Schwager, Smith	1997	$R = -3172 + 7.562P$	Honduras
Torri et al	2006	$R = -944 + 3.08P$	USA (continental)
Renard, Fremund,	1994	$R = 0.04830 P^{1.51}$	
Yu and Rosewell	1996	$R = 0.0438 P^{1.61}$	Australia
Torri et all	2006	$R = - 944 + 3.08P$	Malaysia
Zacchi		$R = (1,1 – 1,5) P$	Italia - Tuscany
Hurni	1985	$R = 0,55*P-24,7$	Ethiopia, Egypt
Sung	1981	$R = 79+0,363*P$	Entire India
Rambabu	1979	$R = 81,5+0,375*P$	India
Eltaif	2010	$R = 23,61*e^{(0,048*P)}$	Jordan
Harper	1987	$R = 38,5+0,35*P$	Thailand
Rogler & Schwertmann	1981	$R = 10 (-1,48+1,48*Ps)$	Germany - Bavaria

Finally were selected 7 equations, and final result per 18 meteorological stations was calculated as mean value of the results from selected equations.

Table 11 - Calculation of R- factor by "real" equations for further modelling

MS	P	Ps	Zachi	Hurni	Sungh	Rambabu	Eltaif	Harper	GERM	Average
Stip	*455,1*	*287*	592	226	244	252	516	198	693	**389**
Skopje	*478,6*	*287,9*	622	239	253	261	542	206	695	**403**
Prilep	*510,1*	*307,6*	663	256	264	273	578	217	744	**428**
D. Kapija	*554,8*	*281,5*	721	280	280	290	629	233	680	**445**
Strumica	*564,4*	*311,4*	734	286	284	293	640	236	753	**461**
Pretor	*594,1*	*304,4*	772	302	295	304	673	246	736	**476**
Berovo	*611,1*	*378,1*	794	311	301	311	693	252	918	**511**
Bitola	*619,9*	*321,6*	806	316	304	314	703	255	778	**497**
K. Palanka	*624,7*	*395*	812	319	306	316	708	257	960	**525**
Gevgelija	*678,6*	*334,1*	882	349	325	336	769	276	809	**535**
Ohrid	*689,9*	*335,6*	897	355	329	340	782	280	813	**542**
N. Dojran	*700,0*	*393,5*	910	360	333	344	793	284	956	**569**
S. Glava	*838,6*	*485,6*	1090	437	383	396	950	332	1183	**682**
Krusevo	*881,3*	*457,9*	1146	460	399	412	999	347	1115	**697**
P. Sapka	*883,4*	*530,1*	1148	461	400	413	1001	348	1293	**723**
Mavrovo	*993,5*	*467,7*	1292	522	440	454	1126	386	1139	**765**
Lazaropole	*1060,4*	*504,6*	1379	559	464	479	1202	410	1230	**817**

- Then using linear regression with altitude was developed map of R-factor of the country.
- $\mathbf{y = 0{,}1471x + 431{,}57}$ or $R = \mathbf{0{,}1471H + 431{,}57}$

- The value of coefficient of correlation – r - was 0,72 – strong uphill linear correlation. The next step was to implement the function of the elevation into continuous map. Using the raster calculator in GIS environment, the produced equations were used to calculate the raster continuous layers for the whole country.

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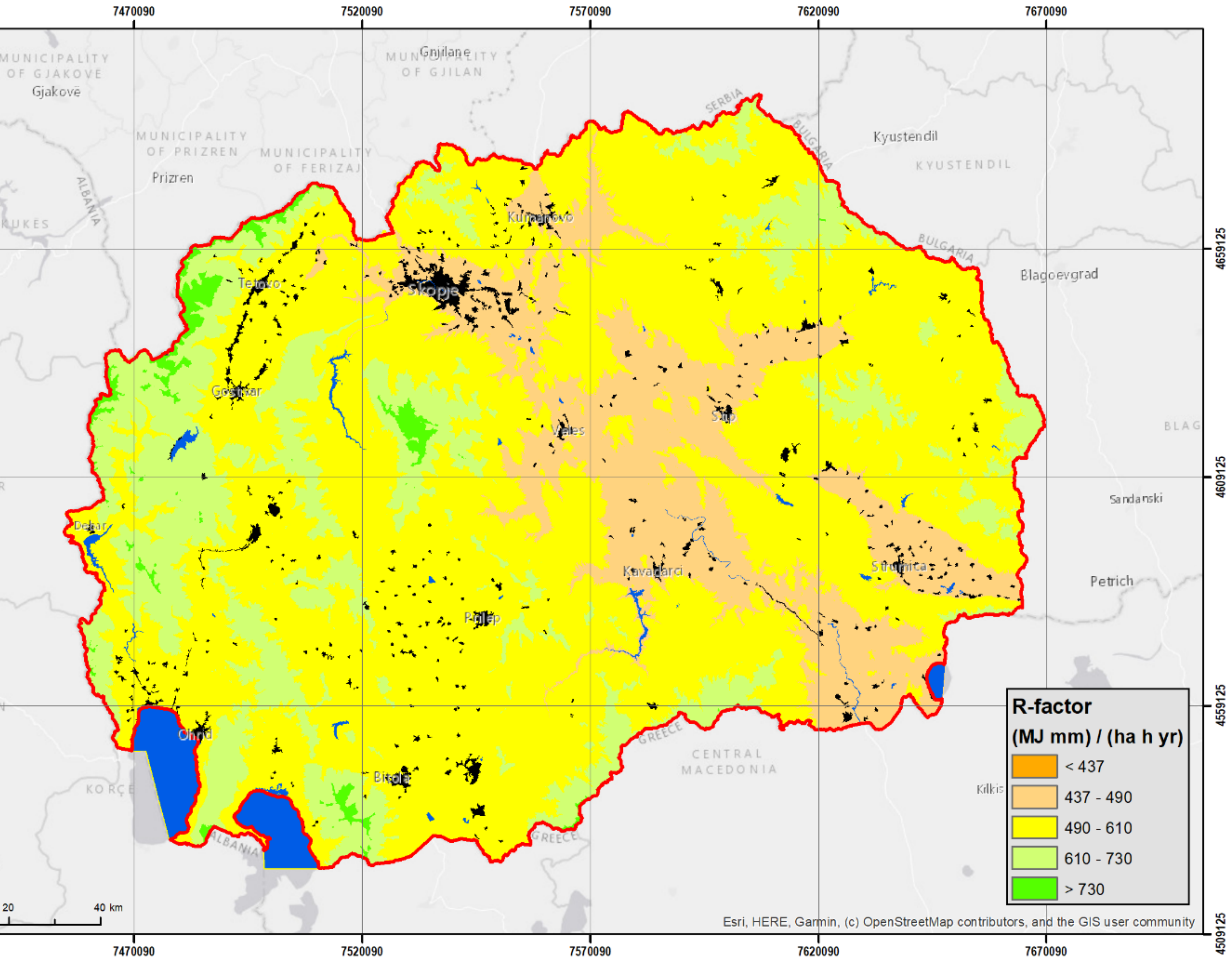

The average value of the R-factor in the country is 533, ranging from 437 in the vicinity of Krivolak in the central part of the country, to 835 in the southwestern part of Šar Planiana and Korab.

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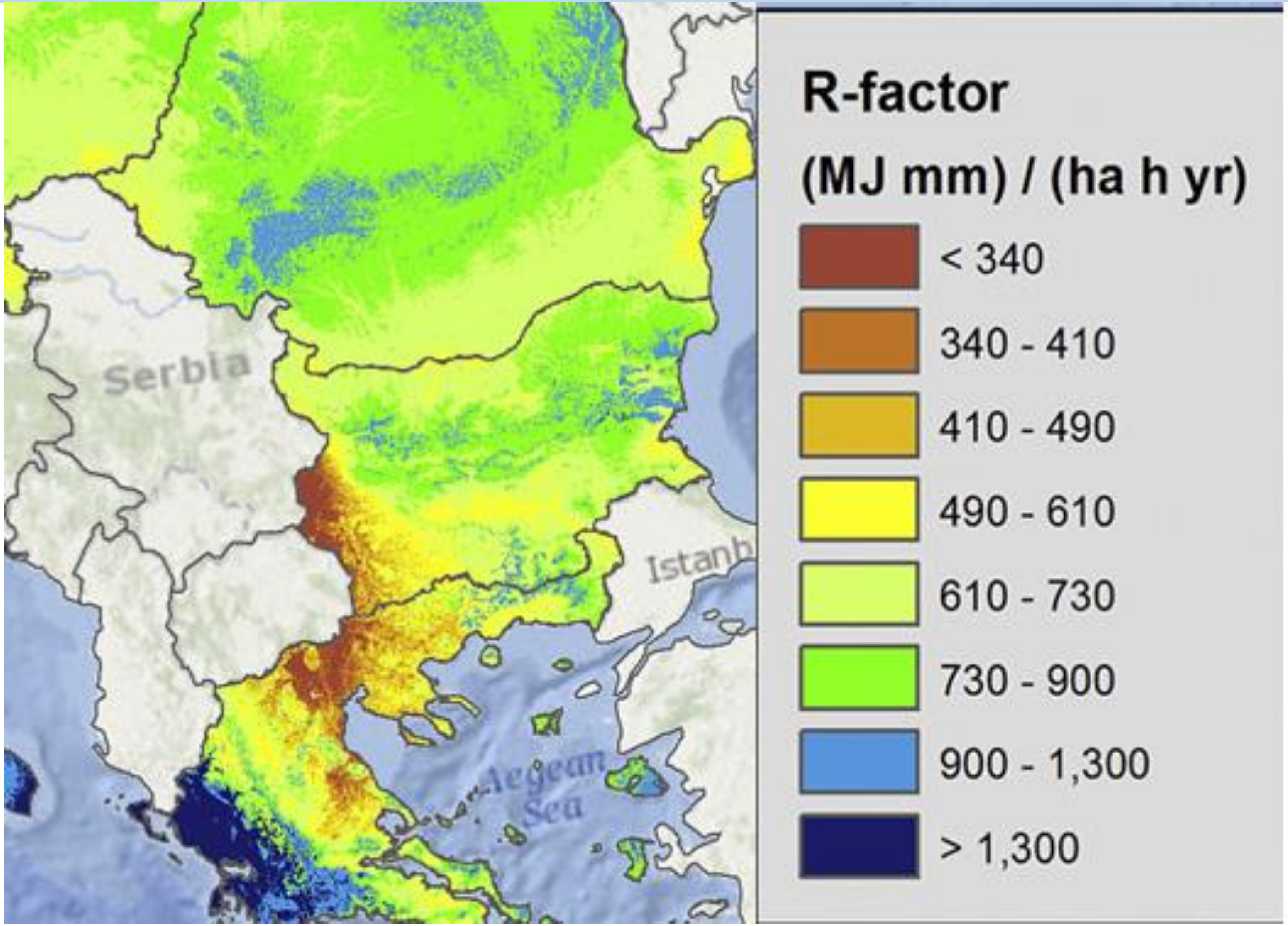
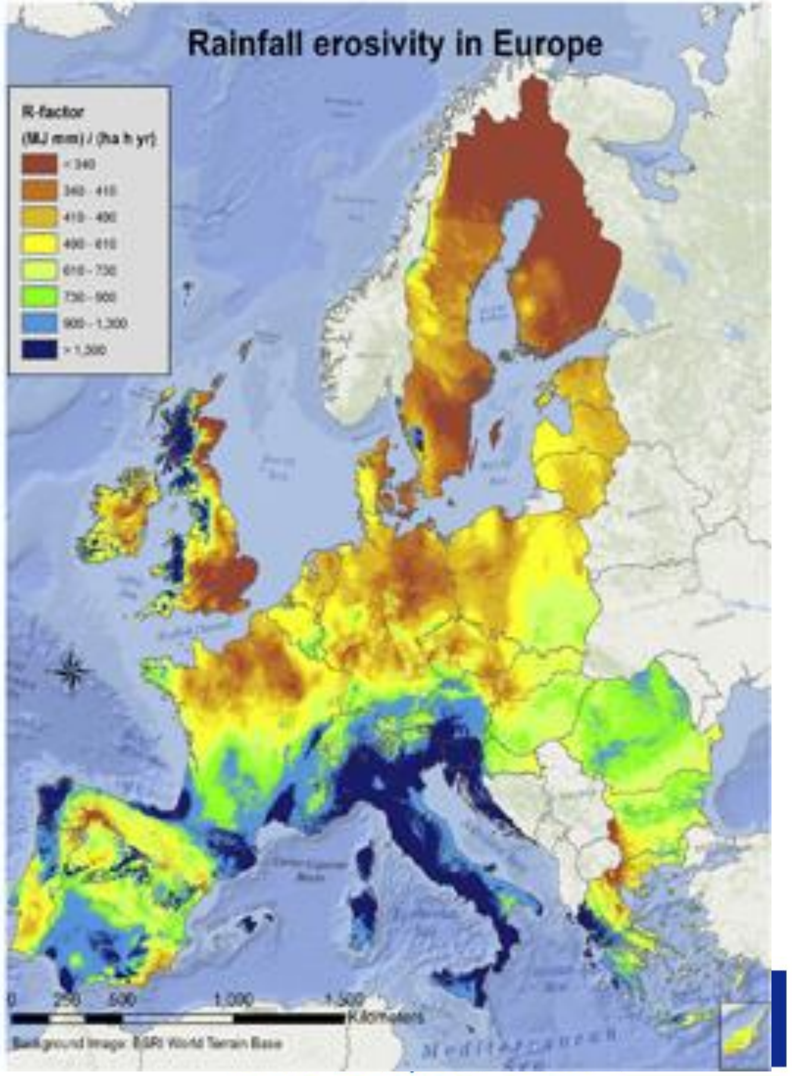
Comparison with values along the border with Greece and Bulgaria





- According to Panagos et al. (2014, 2015), in Greece along the border, in the western values for R are between 400 and 600, while in the central and eastern part between 340 - 490. and in the northern part 340-410. In the high mountains, these values are already present.
- According to the Global R-map (Panagos et al., 2017), values in North Macedonia are generally between 400-700, while in the western part of the country they are > 700.
- For planning works in the western part of the country where the height above sea level reaches 2764 m - Korab peak), the following values are taken as a guide: Rila - Bulgaria (2935 m above sea level), as well as Olimp 2905 - Greece where R is the factor 730-900 (map from 2014-5) or 700-1130 (map form 2017).
- It means that our approach for R factor is an appropriate

Erosion modelling using EPM by Gavrilovic

- On-field mapping of Z (erosion coefficient) and supportive parameters (expert judgment)

- Modelling [Z] using the equation $Z = \gamma * Xa * (\varphi + \sqrt{I_{sr}})$

- Modelling [Wsp] using the equation $Wsp = T \cdot H_{ann} \cdot \pi \cdot \sqrt{z^3}$

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Erosion modelling using EPM by Gavrilovic

$$Z = \gamma * Xa * (\varphi + \sqrt{I_{sr}})$$

- Step 1 – analytical modelling of the parameters and final map using the original tables
- Step 2 – filed trip – direct mapping (expert judgment)
- Step 3 – comparison between 2 models
- if there were larger difference it was checked why it has happen
- it cause necessary of changes in the original tables
- Step 4 – changes in the original tables for various parameters

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4. Erosion modelling using EPM

nula for Z-calculations is presented below:

$$Z = \gamma * Xa * (\varphi + \sqrt{I_{sr}})$$

erosion coefficient by Gavrilovic

reciprocal value of the coefficient of resistance of the soil to erosion (0,25< γ <2,00)

coefficient of regulation of the basin and it takes in consideration the level of protection of the and n erosive forces in natural conditions (X) and artificial conditions (a) (0.01<Xa<1.00).

numerical equivalent of visible and clearly articulated process of erosion in the watershed

- *average slope of the watershed expressed in decimal* value

inal supportive tables for defining necessary parameters for Z – calculation as well as the original hodological approach were modified.

γ – reciprocal value of the coefficient of resistance of the soil to erosion

- Within the original methodology was used an old soil classification system by Skoric, Ciric and Filipovski. Here is used WRB (World Reference Base) classification.
- Classification of rock types is the same.
- Beside it, in various previous calculation of this parameter realized by foreign colleagues was used only geology map that is not correct because over the parent rocks there are soil layers with different depth. Thus e.g. there is magmatic rock where value is 0,25 but over is soil layer e.g. cambisol with value 0,8 (big difference)
- The main princip is that above the rock layer is soil that is directly exposed to erosion forces: water, wind, sun etc. especially in a case of bare soil.
- Taking in consideration all above, the original table was modified with change of soil types according to WRB classification and including missing soil types

Table 4 - Values of γ coefficient - (modified by Blinkov and Mukaetov, 2020)

No.	Soil and rock types	γ
1.	Sand, gravel and un-cohesive soils, Urbic Anthrosol (deposol), Talus cones	2,0
2.	Arenosols, Stepic soil - Salty soils (Solonetz and Solonchak) , Tuff,	1,6
3.	Aric/Spolic Regosol (Regosol) , Leptosol (Lithosol), Colluvium (Coluviual), Volcanic breccia	1,4
4.	Rendzic leptosol (Calcomelanosol), Decomposed limestone and marl, Flish sediments,	1,2
5	Rendzina, Serpentinite,	1,1
6	Podzol, parapodzol, decomposed schist, mica schists, argyloschist, gneiss	1,0
7	Ferric Luvisol on hard limestones (Terra rosa), Humic Eutric regosol leptosols (Ranker), Vigor and shaled limestones,	0,9
8	Eutric and District Cambisol, Chromic Leptic Luvisol on hard limestones (Calcocambisol), Chromic Luvisol on saprolite (Chromic Cambisol)	0,8
9	Vertisol, Gleysoil, Molic fluvisols,	0,6
10	Fluvisol - Alluvial soils with good structure, Chernozem,	0,5
11	Bare compact eruptive rocks	0,25

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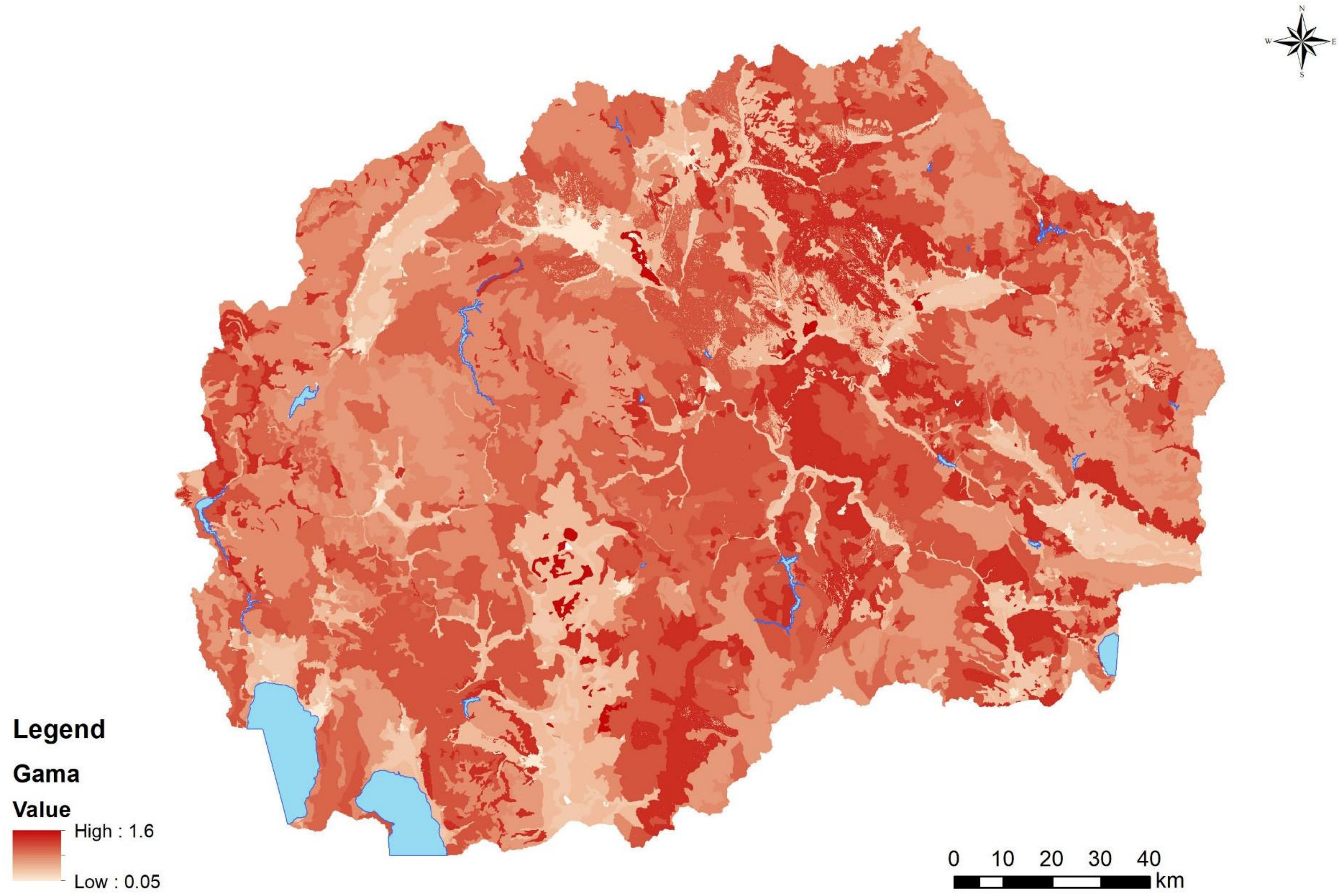
γ –
reciprocal value of the coefficient of resistance of the soil to erosion



Xa – coefficient of protection of the basin/area and it takes in consideration the level of protection of the and from erosive forces in natural conditions (X) and artificial conditions (a)

- This coefficient varies from 0.01 to 1.00. The most significant changes from all parameters were done in the tables and approaches for defining this parameter.
- Taking in consideration modelling on a level of the country , as a basic land cover data were used available sources especially CORINE LCU 2018 and FAO land cover (2017).
- Firstly, within the tables were included LC class according to the CORINE LCU classification. Corine LCU contains 44 classes, and is presented as a cartographic product, at a scale of 1:100 000, polygons are wide and some classes are not precise enough. The most significant changes were done in the classes: broadleaved forest, mixed forest, pasture and natural grasslands

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- It should be noted that for the engineering purpose, the only fully correct approach is to implement on field mapping.
- For cartography needs, various scientists use existing maps f.e. CORINE LCU. The scale and accuracy of CORINE LC database is not fully in accordance with erosion modelling.
- Taking in consideration the above, further detailed breaking of existing polygons into smaller ones according to the protection of erosion forces was derived through remote sensing techniques, using satellite images and aerial photo detection and validation through filed work.

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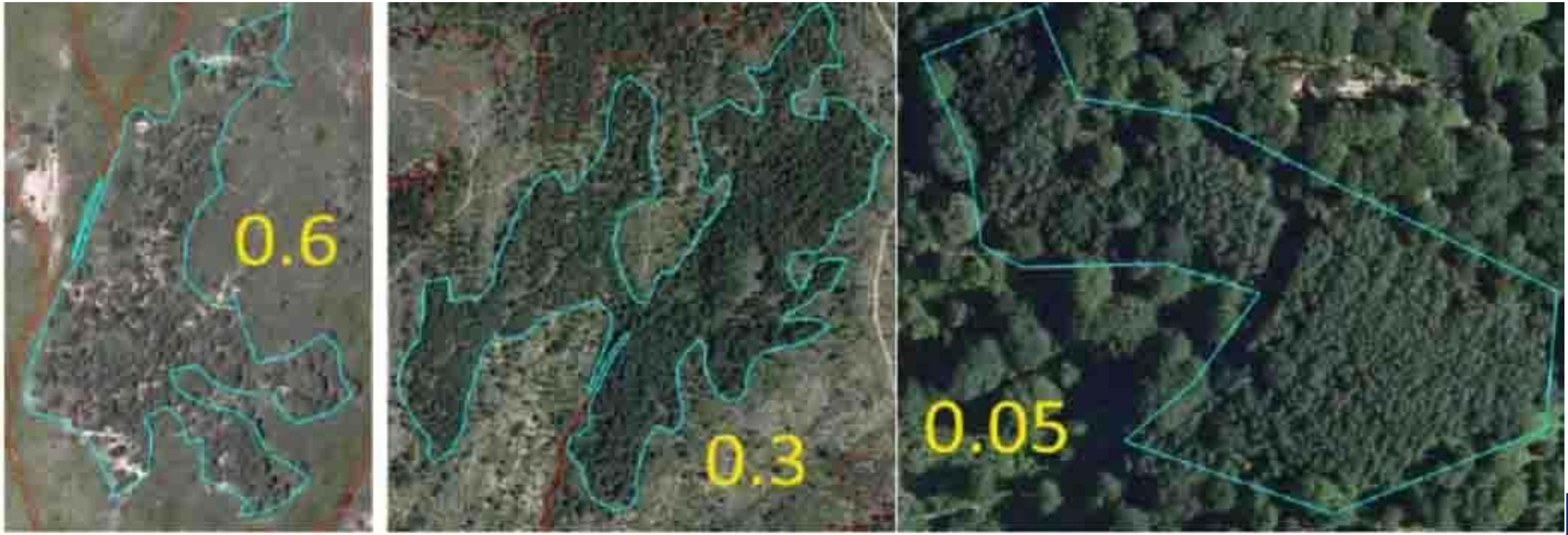
Class forests

7	Transitional woodland-shrub; (*Degraded forests with eroded land)*	0,5-0,7	1,0	0,5-0,7
9	Sparse broadleaved forests (depend of cover percent) 0,2-0,6	0.2-0.6	1.0	0.2-0.6
10	Coniferous, Broadleaved, Mixed Forests (Forest with good structure)	0,05-0,2	1,0	0,05 - 0,2



- According to CORINE LCU some area in the central zone of the country are classified as
- 321- natural grassland or 324 – Sclerophyllous vegetation and somewhere as transitional woodland and shrubs. In fact, this area is bare and erosion processes are significant.

3	Lowland grasslands in region vulnerable to desertification	0,85
6	Natural Grasslands; Sclerophyllous vegetation *(Mountain pastures)*	0,6

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N0	Conditions that affect the value of the coefficient X and a	Mean value		
		X	**a**	**X.a**
I River basin or area before undertaking anti-erosion works and measures				
1	Open spaces with little or no vegetation (*Completely bare, untilled land) and mined, dump and construction cites*	1,0	1,0	1,0
2	Arable land (*Arable land tilled by plowing through and against*)	0,9	1,0	0,9
3	Lowland grasslands in region vulnerable to desertification	0,85	1,0	0,85
4	Heterogeneous agriculture areas	0,8	1,0	0,8
5	Permanent crops (*Orchard and vineyards without ground vegetation*)	0,7	1,0	0,7
6	Natural Grasslands; Sclerophyllous vegetation *(Mountain pastures*)	0,6	1,0	0,6
7	Transitional woodland-shrub; (*Degraded forests with eroded land)*	0,5-0,7	1,0	0,5-0,7
8	Pastures; (*Meadow areas under clover and similar perennial crops*)	0,4	1,0	0,4
9	Sparse broadleaved forests (depend of cover percent) 0,2-0,6	0.2-0.6	1.0	0.2-0.6
10	Coniferous, Broadleaved, Mixed Forests (Forest with good structure)	0,05-0,2	1,0	0,05 - 0,2

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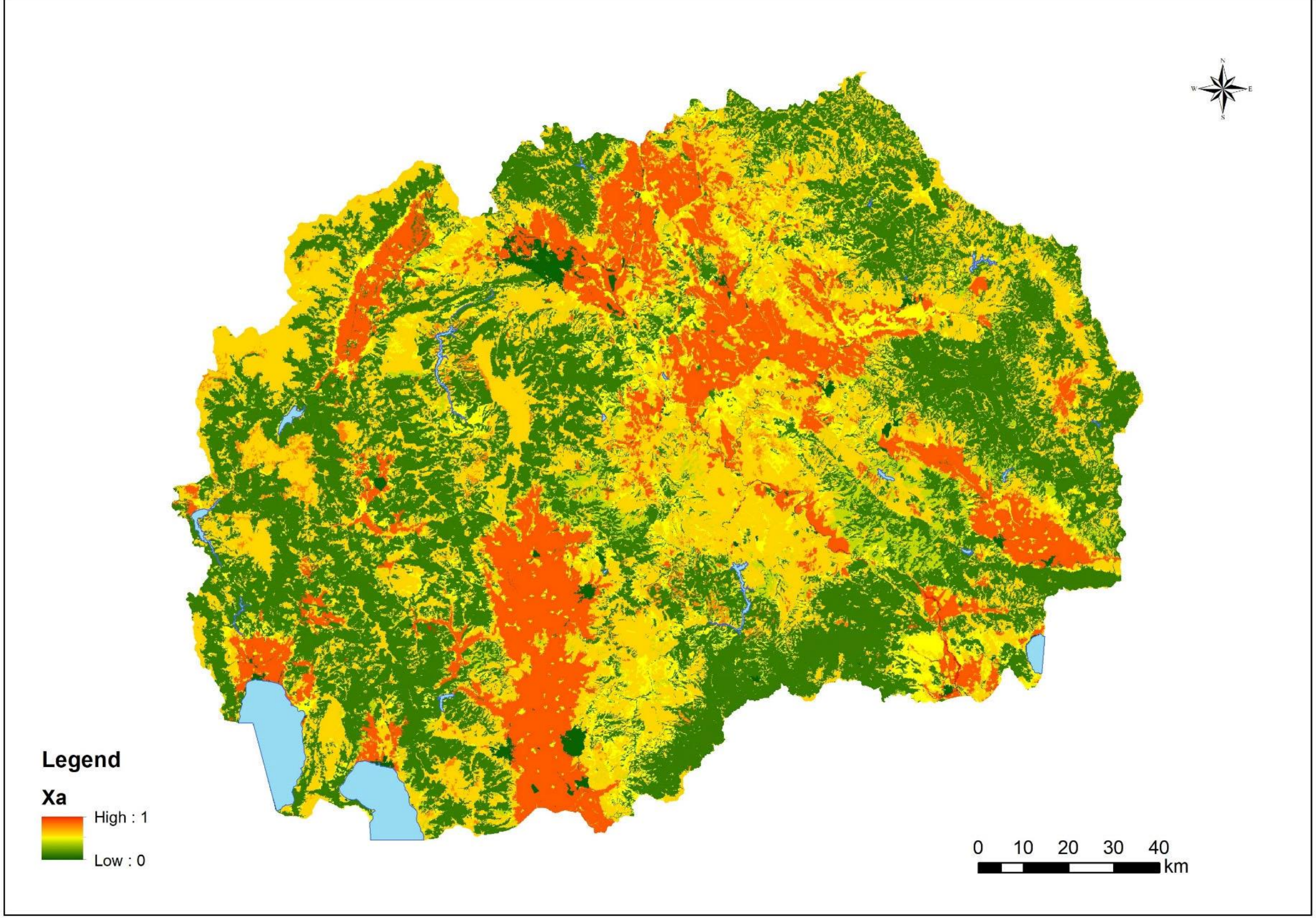
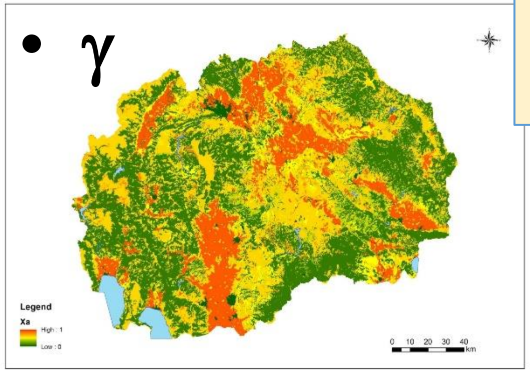
- Final
- Xa map

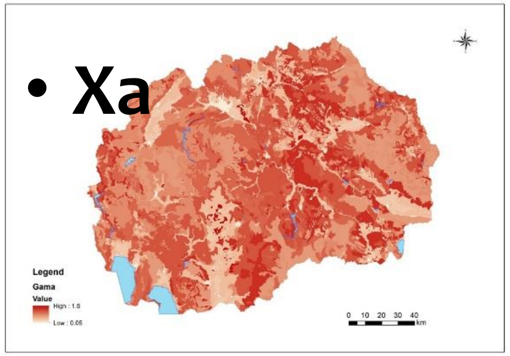


Z – coefficient – raster map

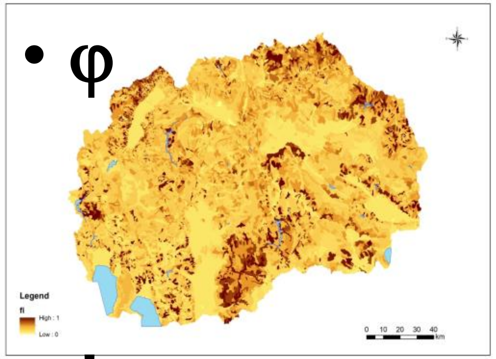
- γ



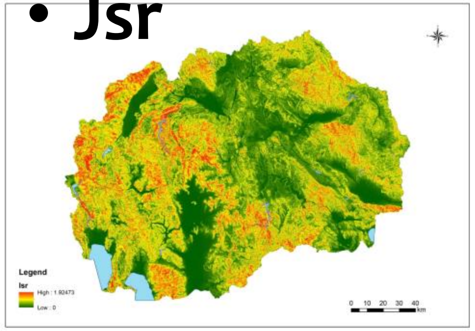
- Xa



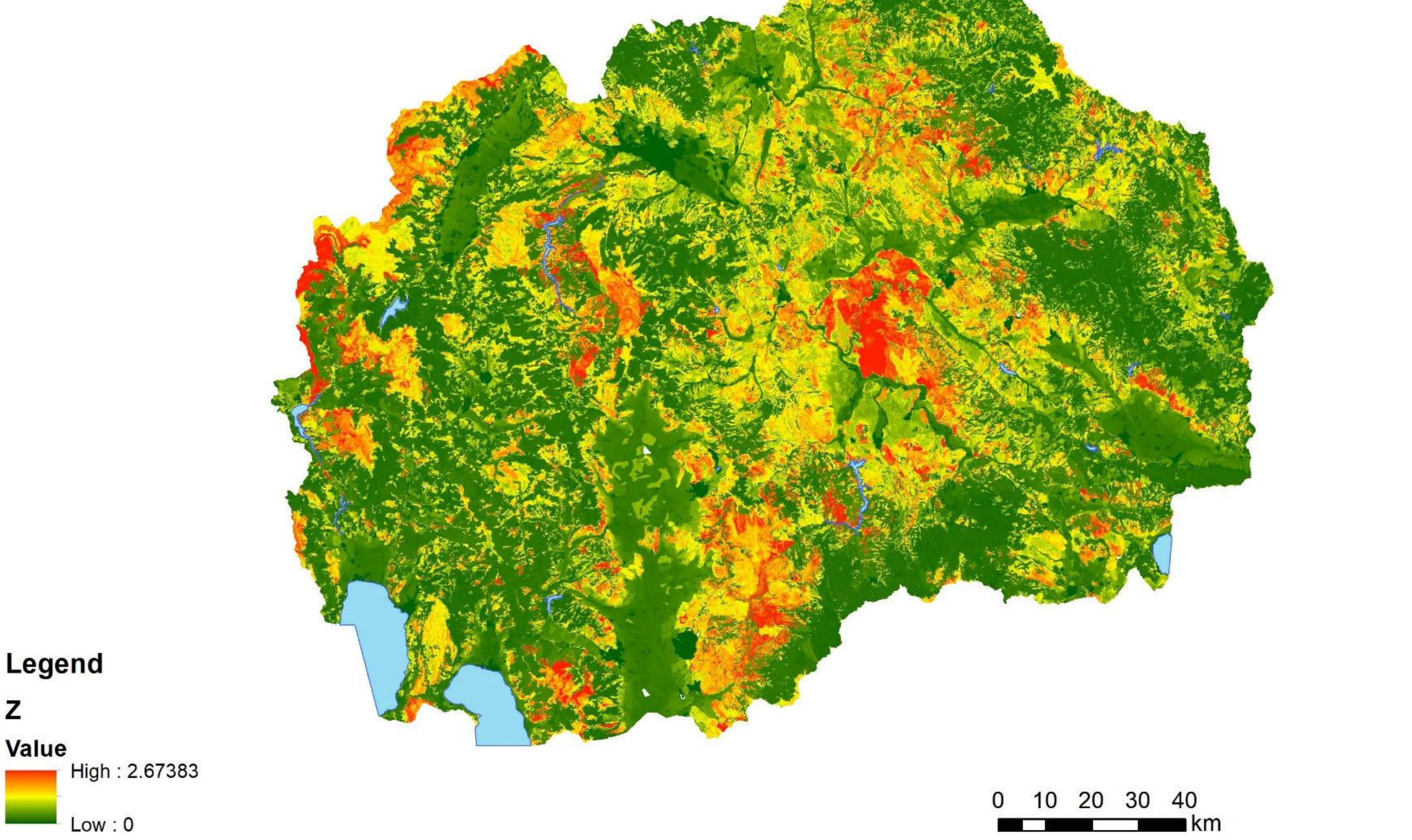
- φ

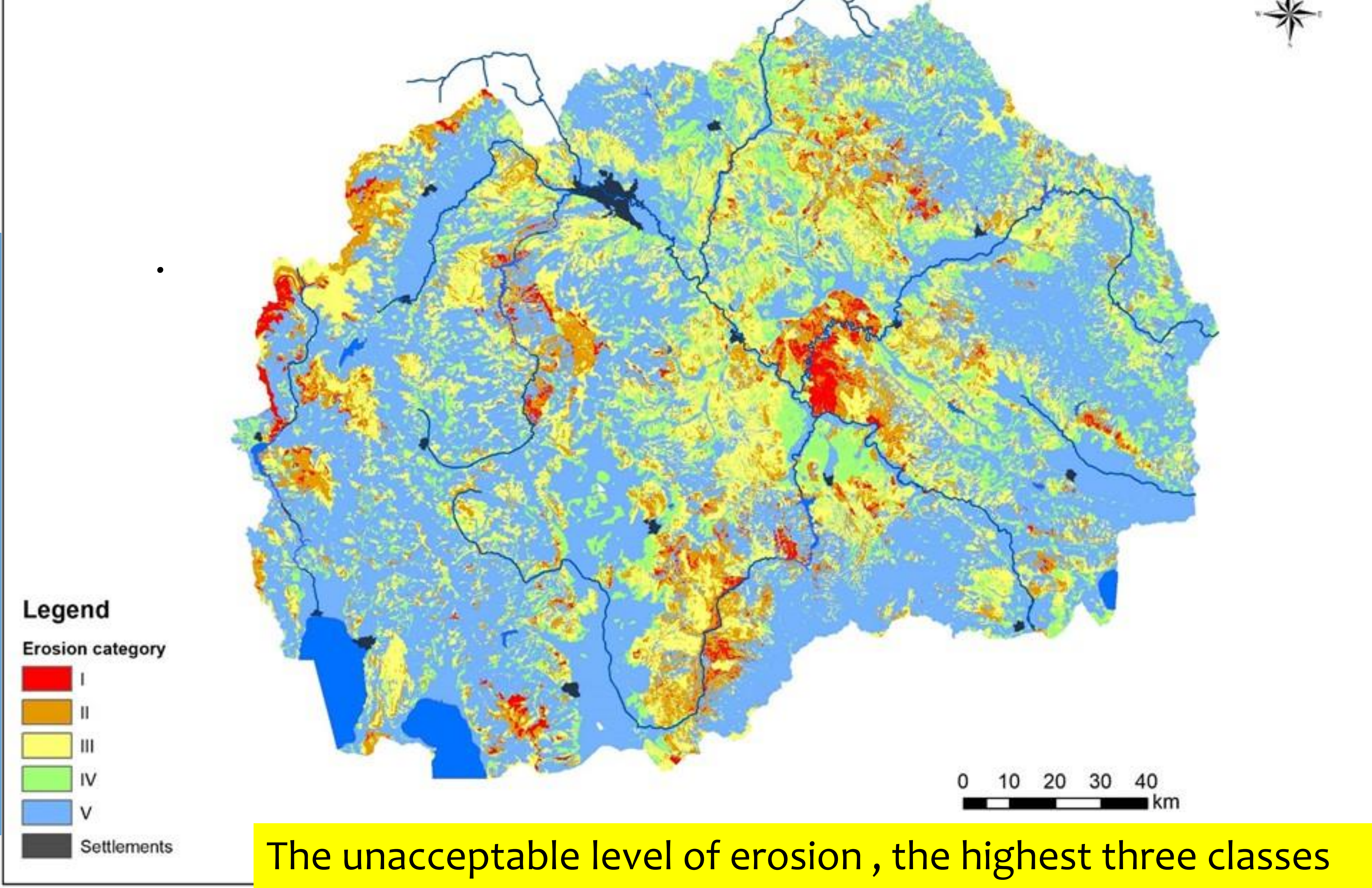


- Jsr



$$Z = \gamma * Xa * (\varphi + \sqrt{I_{sr}})$$





Z – coef. – erosion categories

The unacceptable level of erosion , the highest three classes (I-III), cover 834.130 ha or 33,57 % of the land territory

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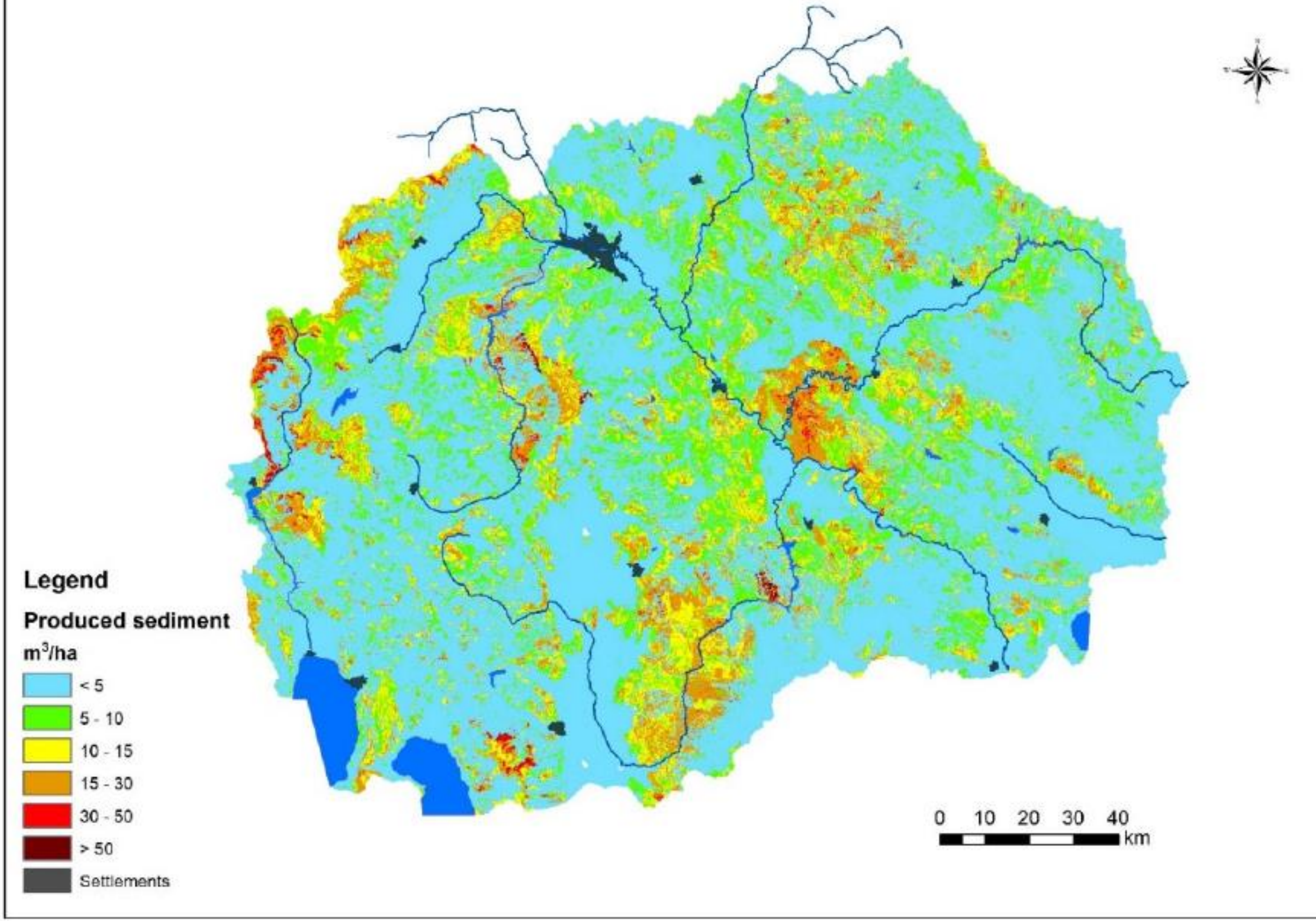
Wsp – mean annual specific production of erosive material

[m^3/ha]



Disadvantages

- Due to some disagreements with the investor – UNEP and BFSD (first it was agreed to work only on a region vulnerable to desertification) as well as the short time for the project implementation, Western Macedonia as well as some other parts are not covered with filed trip in detail even though we had data from previous projects.

- - Due to the previously mentioned reasons, there was no time for delineation in detail terrains with rocks on the surface,

- High sources of erosive sediment (weathering, landslides, gullies) are also not delineated due to the scale of modeling where they are present as line od dot. .

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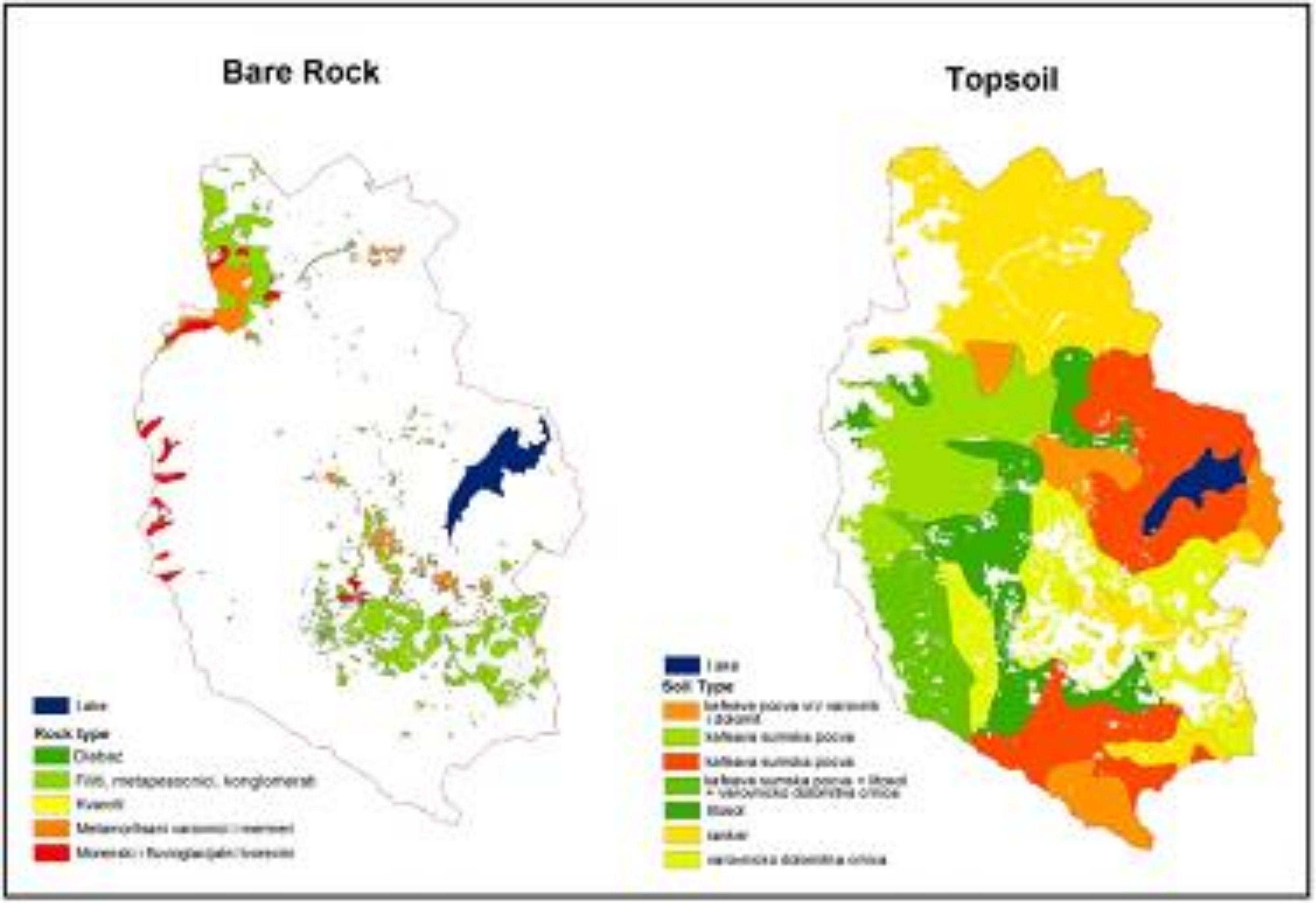
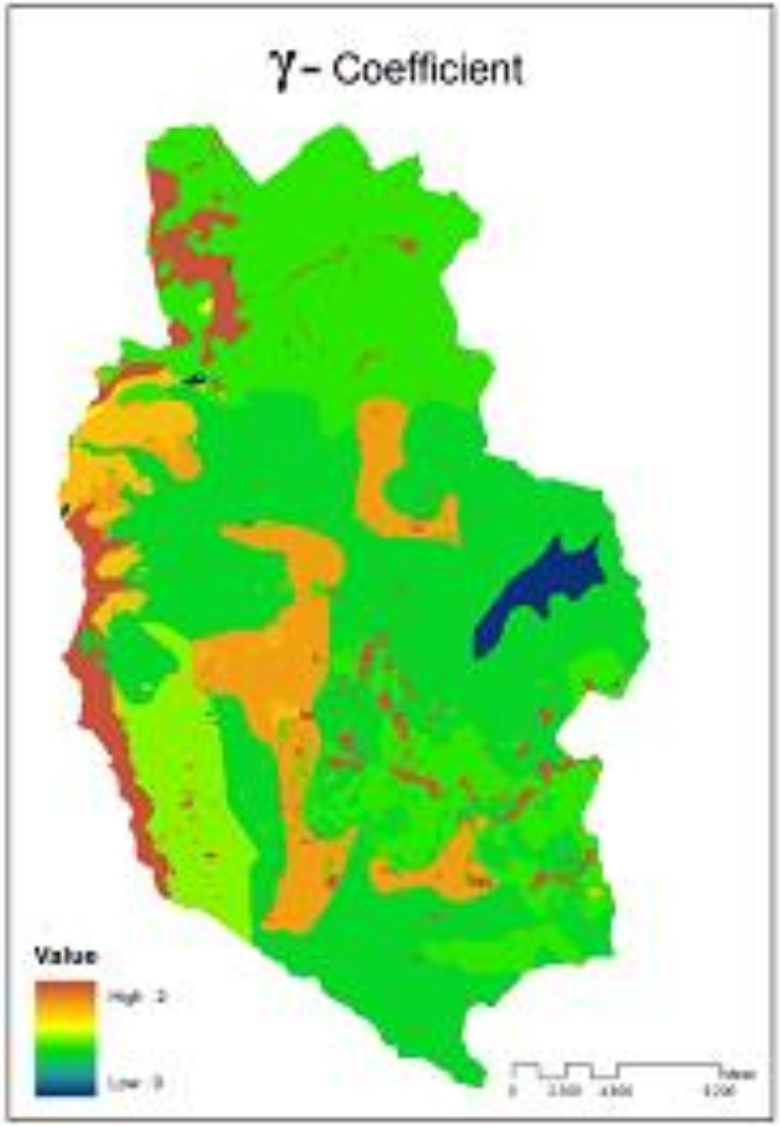
γ – delineation of bare rocks

Kojcevska Tatjana – MSc thesis





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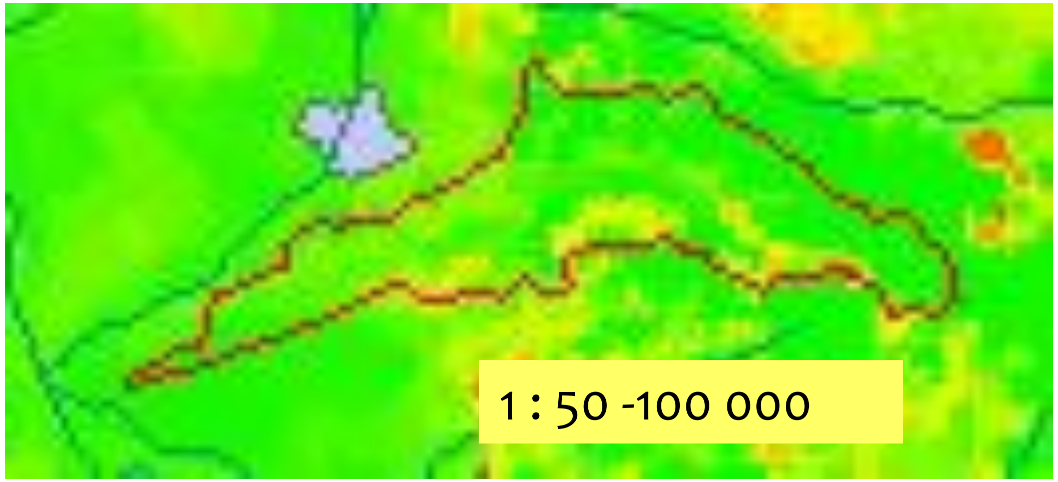
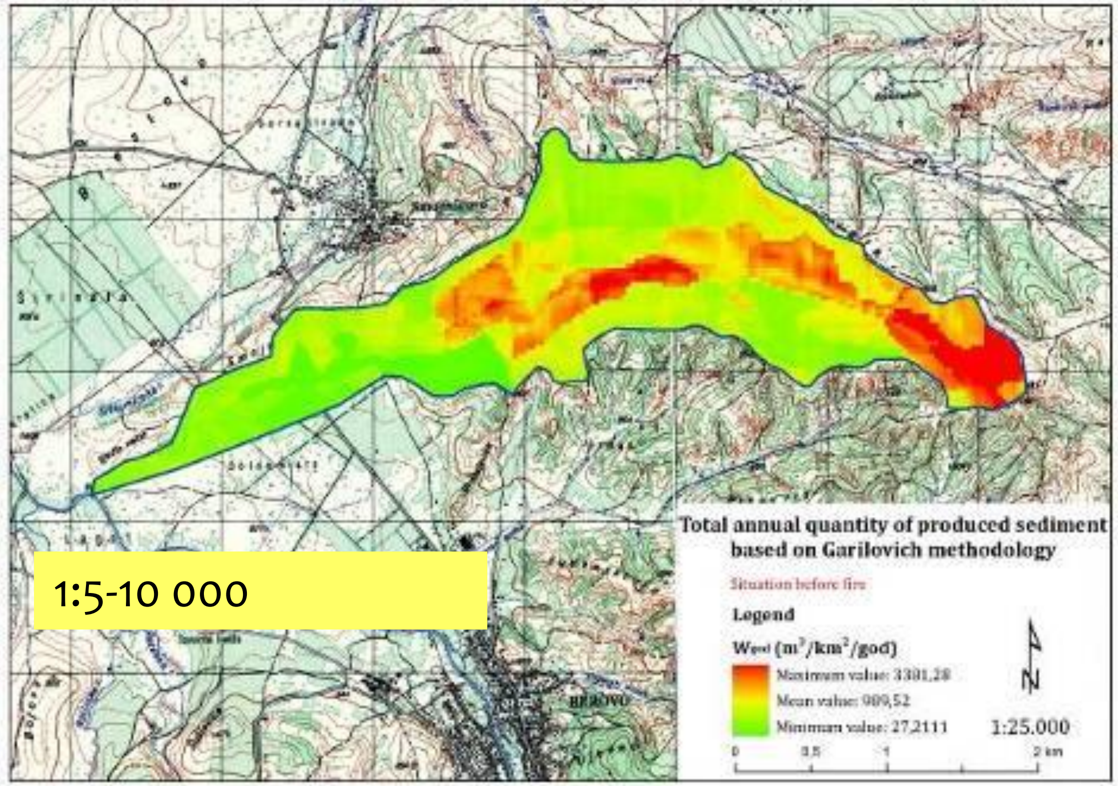
Accuracy of the scale of input parameters

Bozin Trendafilov , MSc thesis





	W-clip	W-detail	increase
Minimum	4,88	27,21	5,58
MEAN	**188,72**	**989,52**	**5,24**
Maximum	2375,69	3381,28	1,97

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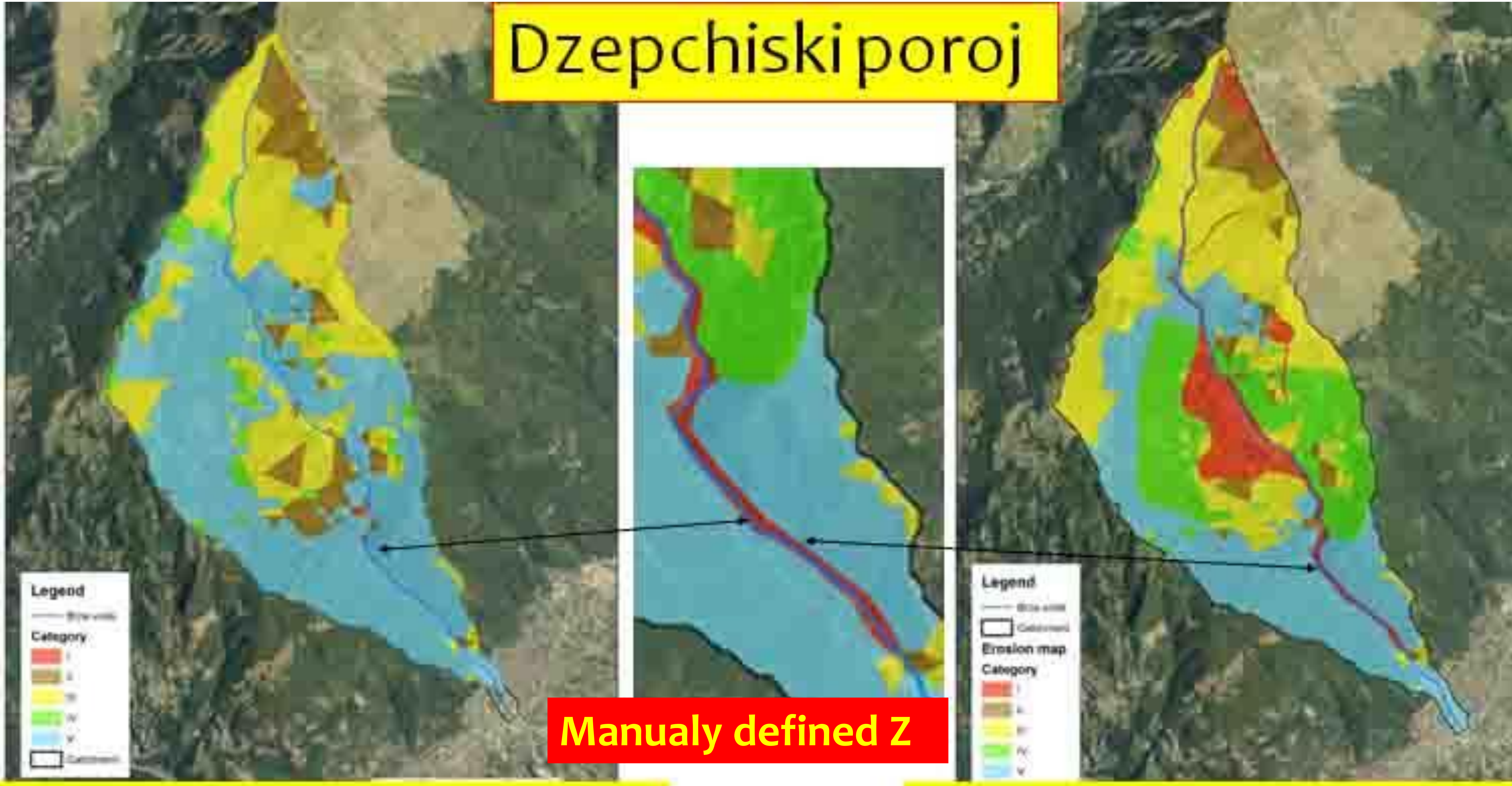
Dzepchiski poroj



Map - North Macedonia 2020

Map - Feasibility Study - 2022

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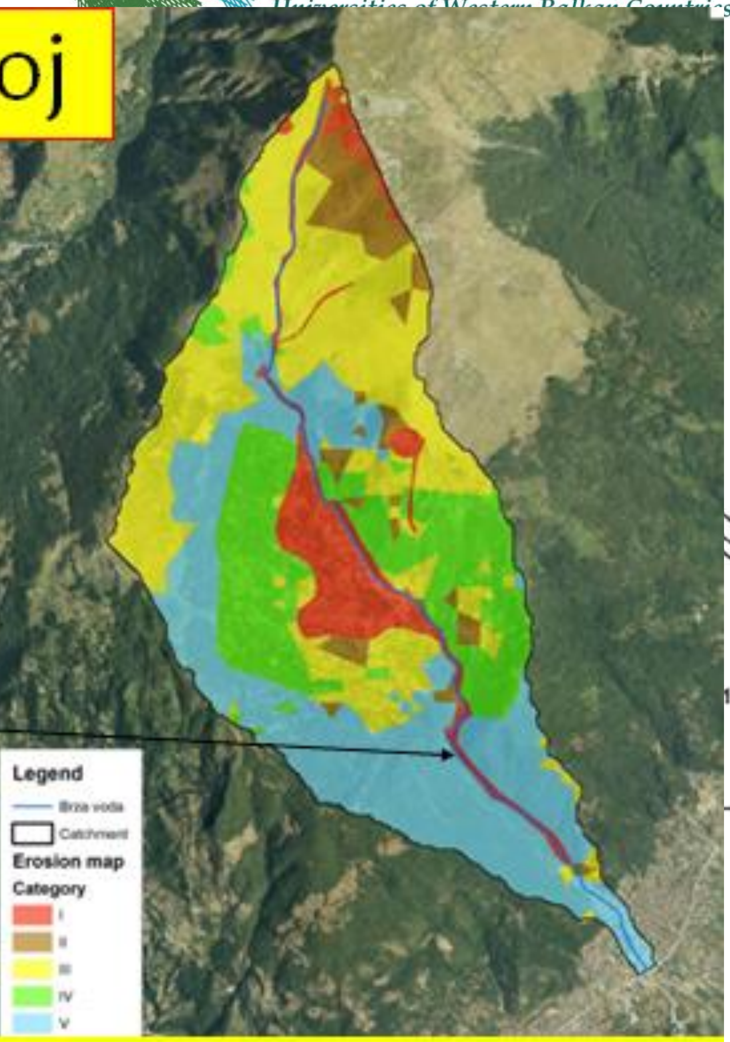
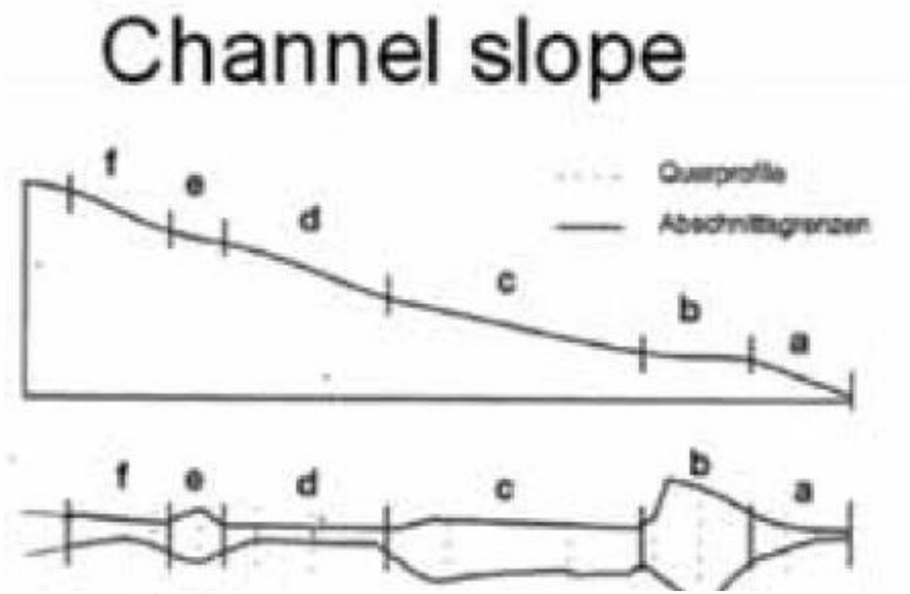
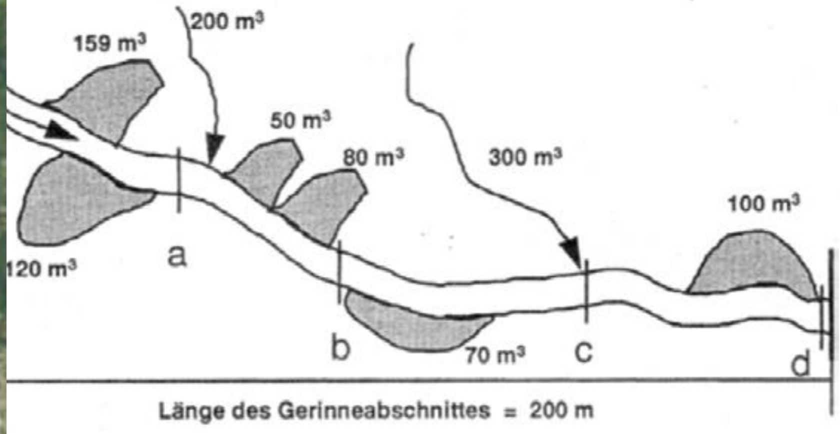
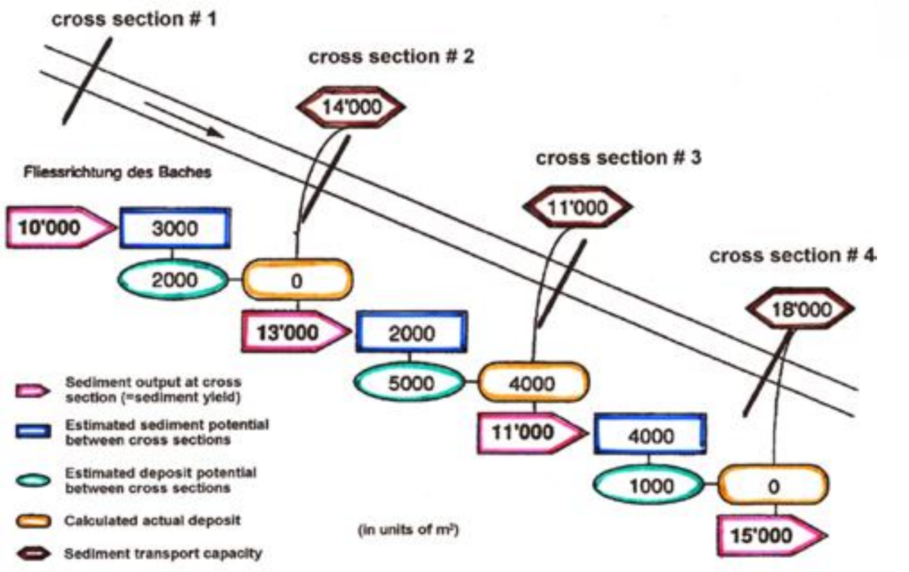
Engineering designing torrents in the Western Macedonia
- fluvial processes -









Gertsch, Lehmann, Spreafico, 2012

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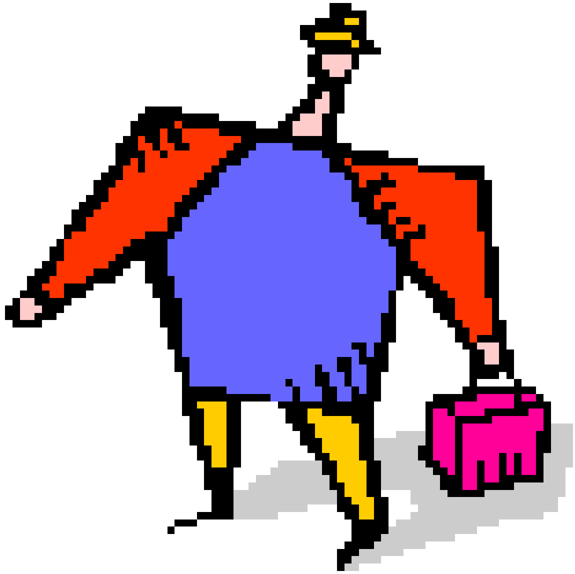
Blagodaram na vnimanieto

Thank you for your attention!



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