HANS EM
FACULTY OF FOREST SCIENCES
LANDSCAPE ARCHITECTURE AND
ENVIRONMENTAL ENGINEERING

SETOF Soil Erosion and TOrrential Flood
Prevention: Curriculum Development at the Universities of Western Balkan Countries

"Development of soil erosion, aridity, drought and desertification maps of the Republic of North Macedonia"

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Министерство за животна средина и просторно планирање

Republika e Maqedonisë së Veriut
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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 – High risk zones and biodiversity

DEFINITIONS

Aridity is a climate phenomenon characterized by a shortage of water. It is a long-term phenomenon, being measured by comparing long-term average water supply (precipitation) to long term average water demand (evaporation and plant transpiration).

Drought is a naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems.

Land degradation means reduction or loss, in arid, semi-arid and dry sub-humid areas, of the biological or economic productivity and complexity of rain fed cropland, irrigated cropland or range, pasture, forest and woodlands resulting from land uses or from a process or combination of processes, including processes arising from human activities and habitation patterns such as: soil erosion caused by wind and/or water; deterioration of the physical, chemical and biological or economic properties of soil; and long-term loss of natural vegetation.

Desertification means land degradation in arid, semi-arid and dry sub-humid areas resulting from various factors, including climatic variations and human activities.

Drylands are arid, semi-arid or dry sub-humid areas, in which the ratio of mean annual precipitation to mean annual potential evapotranspiration lies between 0,05 and 0,65. Areas with a ratio of less than 0,05 are considered hyper-arid deserts. (Source: UNCCD. ICCD/CRIC(9)/CRP.1)

Common basic database

- **Topography data** – EPM, RUSLE, Aridity and Drought ,
  - Various topography maps - EPM, RUSLE, Aridity and Drought ,
  - Digital Elevation Model - for EPM, RUSLE, Aridity and Drought ,
  - Slope map - for EPM, RUSLE, Aridity and Drought ,
  - Drainage (Hydrography) map and data – for EPM,
- **Climatology data**
  - Isothermal map and database - EPM, Aridity and Drought ,
  - Precipitation map and database – EPM, RUSLE, Aridity and Drought ,
  - Data about solar radiation - Aridity and Drought
  - Phenological data - Aridity and Drought
- **Geology data** - for EPM, RUSLE, Aridity and Drought ,
  - Basic geology (petrography) map and data - for EPM
  - Engineering geology map and data – for EPM -

The Team reclassified the basic data according to the methodologies needs (EPM, RUSLE, Aridity and Drought).

Soil Information System (MAKSOIL) , for EPM, RUSLE, Aridity and Drought,

Basic Soil map - for EPM, RUSLE, Aridity and Drought, Content of organic matter, RUSLE, Content of sand,silt,clay , RUSLE, Aridity and Drought, Soil texture map - RUSLE, Aridity and Drought,

Land Cover/Use map and data

CORINE Land Cover 2018 - for EPM, RUSLE, AD ,
FAO land cover data - for EPM, Aridity and Drought
Aerial and Satellite images - for EPM

Previous data about erosion – EPM, RUSLE

Data about erosion control works in various regions – EPM, RUSLE,
The old erosion map and database from 80s – EPM,
Results from measuring sedimentation into the reservoir for control of final result – EPM

Data collected during on-filed activity – EPM, Aridity and Drought

Biodiversity related data

Other data – various national and international studies

ARIDITY

ARIDITY INDEX

- **FAO – UNEP Approach**
- **Bagnouls-Gaussen Aridity Index (BGI)**

BASIC DATA

18 meteorological stations

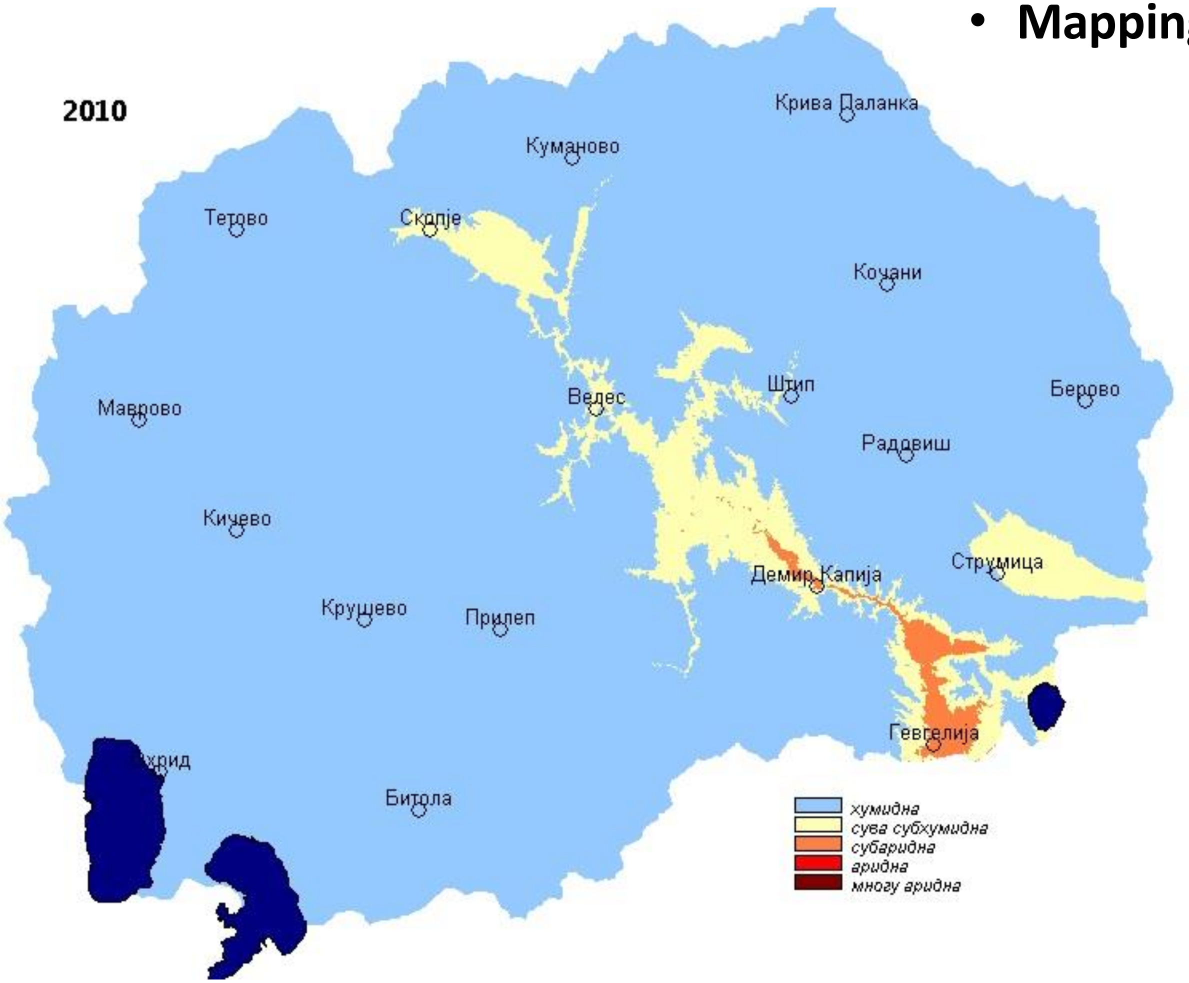
30 years - 1981 – 2010 database

GIS Interpolation

- **Simple linear regression**
- **Kriging method**

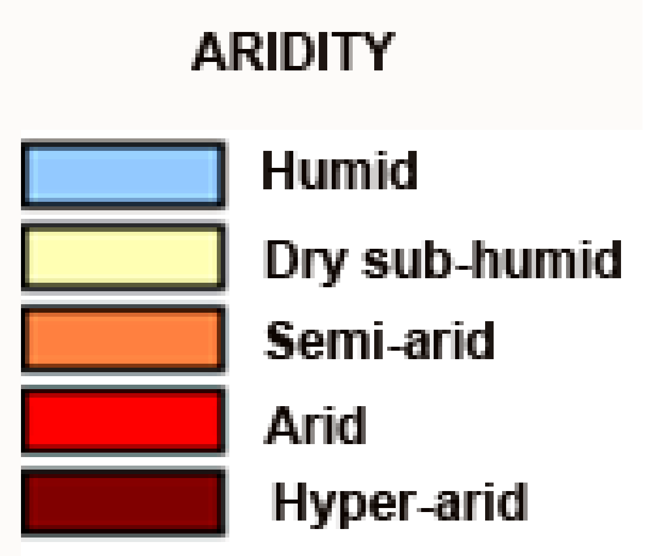
Aridity modelling – 30 years (1981 – 2021)
Annual values of aridity index

- **Aridity**
  - **Aridity index – calculated according UNEP definition**
  - **Potential evapotranspiration - calculated using Penman- Monteith equation**
  - **Mapping of aridity index and GIS spatial interpolation dilemma**

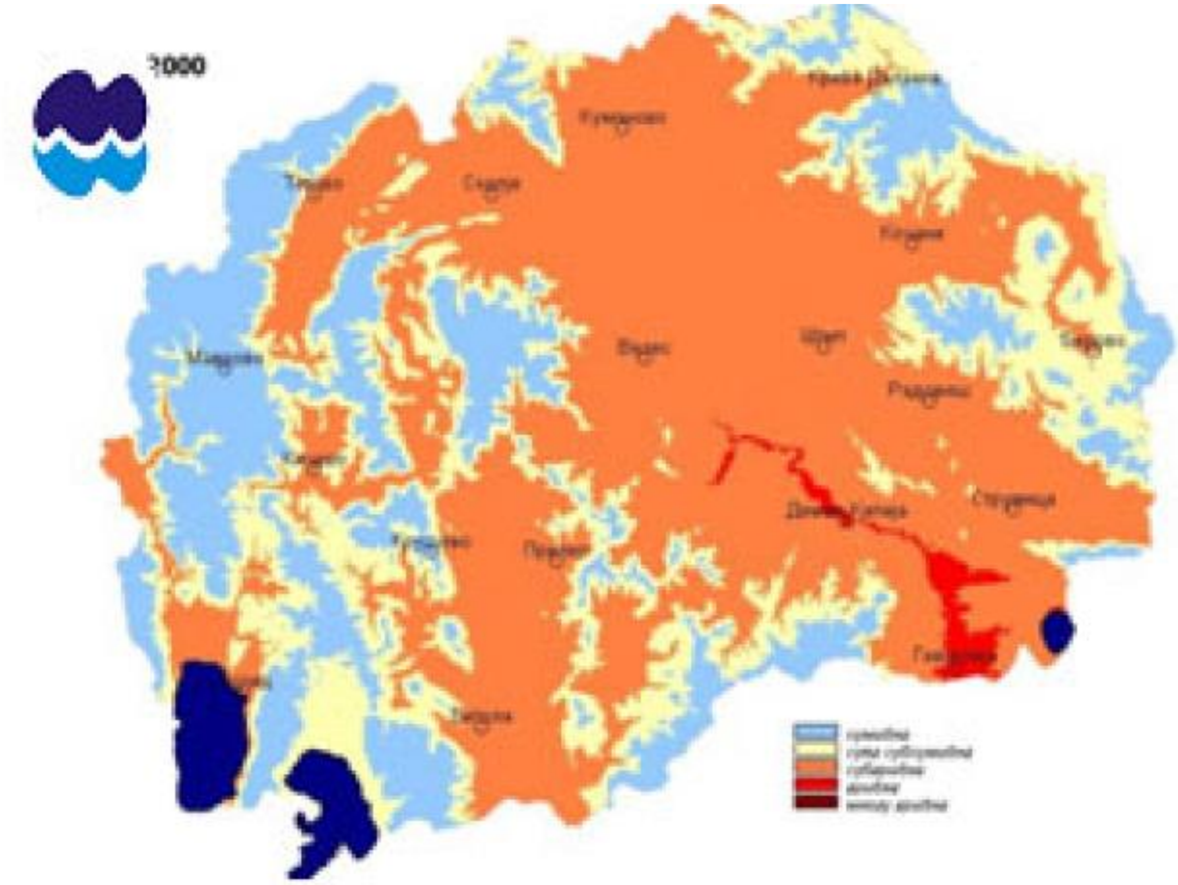


$$AI = \frac{\sum_{i-1}^{30}\left(\frac{P_i}{PET_i}\right)}{30}$$

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma\frac{900}{T+273}u_2(e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)}$$



2000

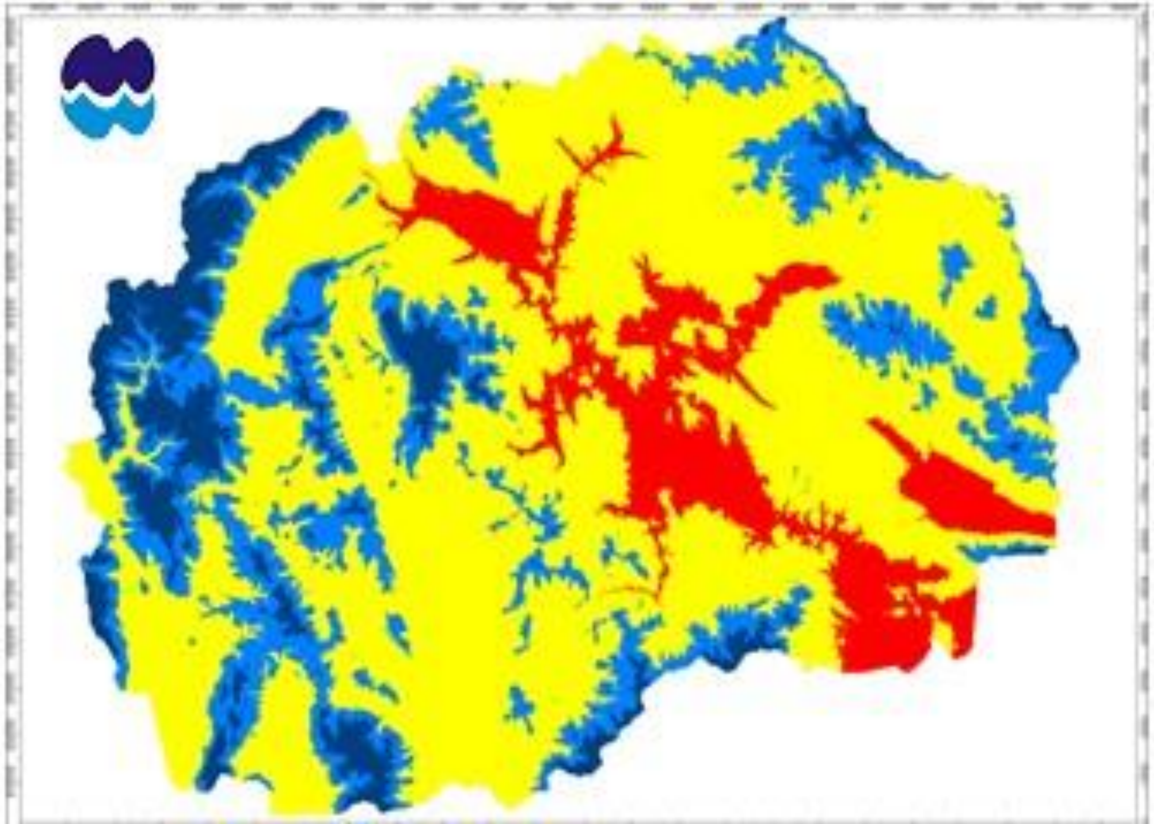


2002

Bagnouls-Gaussen Aridity Index (BGI)

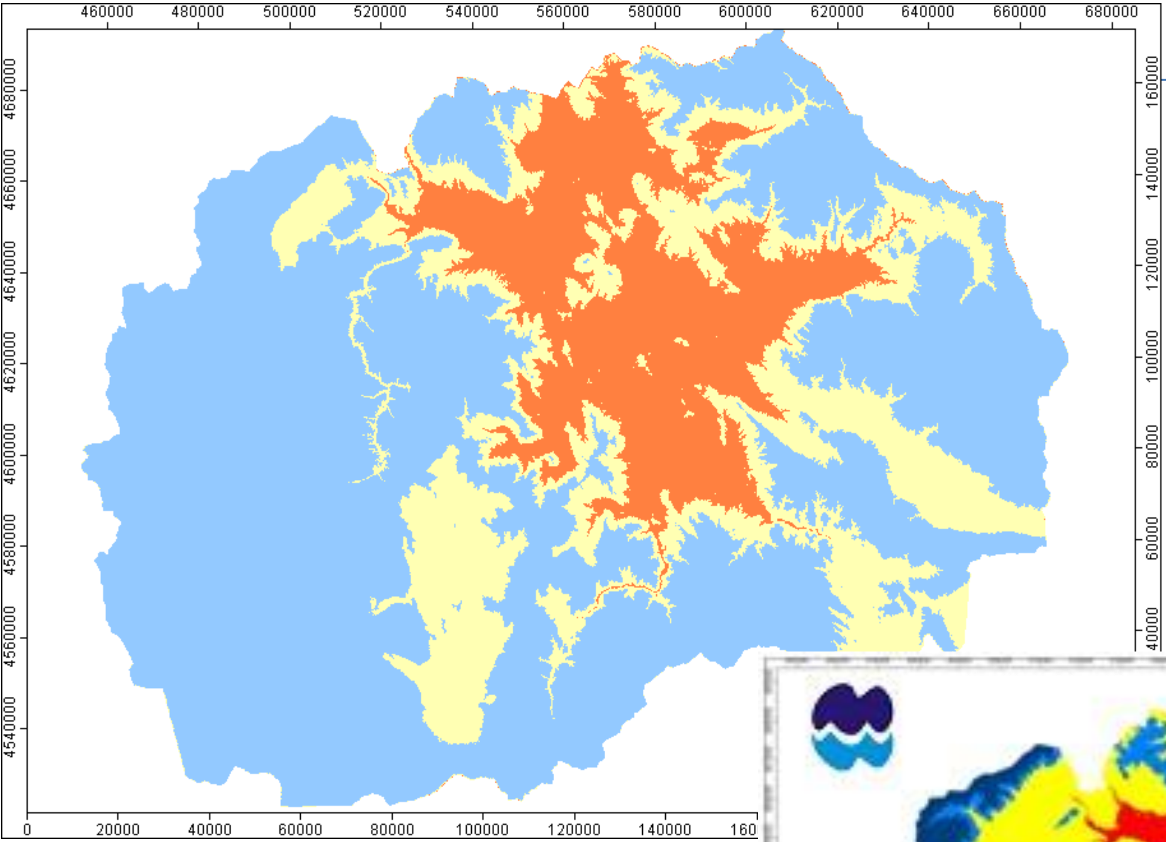
$$BGI = \sum_{i=1}^{n} (2ti - Pi)^{*}k$$

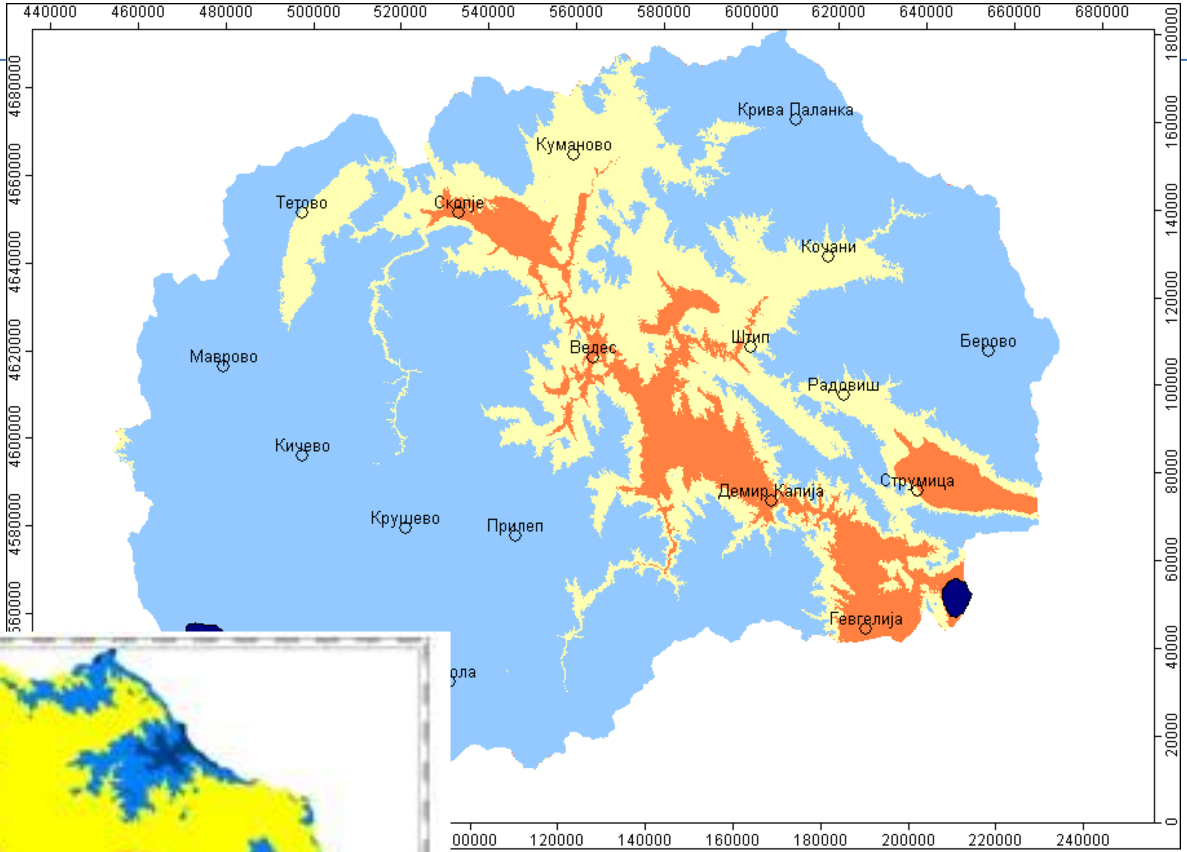
- ti - mean air temperature for month i (°C),
- Pi - total precipitation for month i (mm) and
- k - the proportion of month during which 2ti - Pi >0
- k value is determined by ombro-thermic diagram

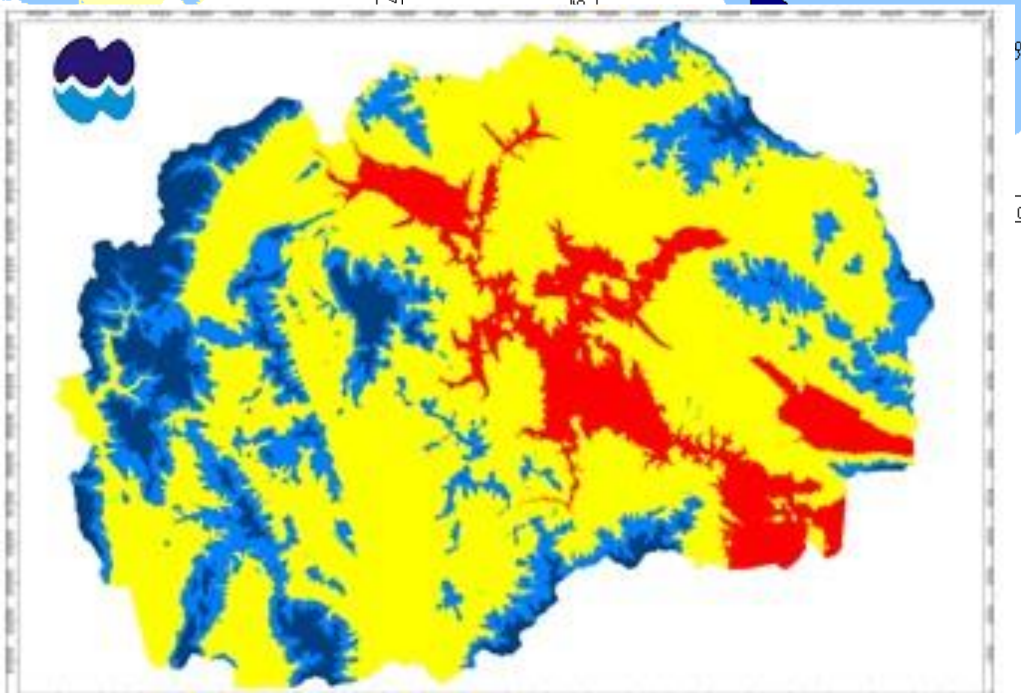


Aridity class	Description	BGI
1	Humid	< 0
2	Moist	0 - 50
3	Arid	50 - 130
4	Very arid	> 130

Aridity index 2 different interpolation (Krigging and Linear regression)

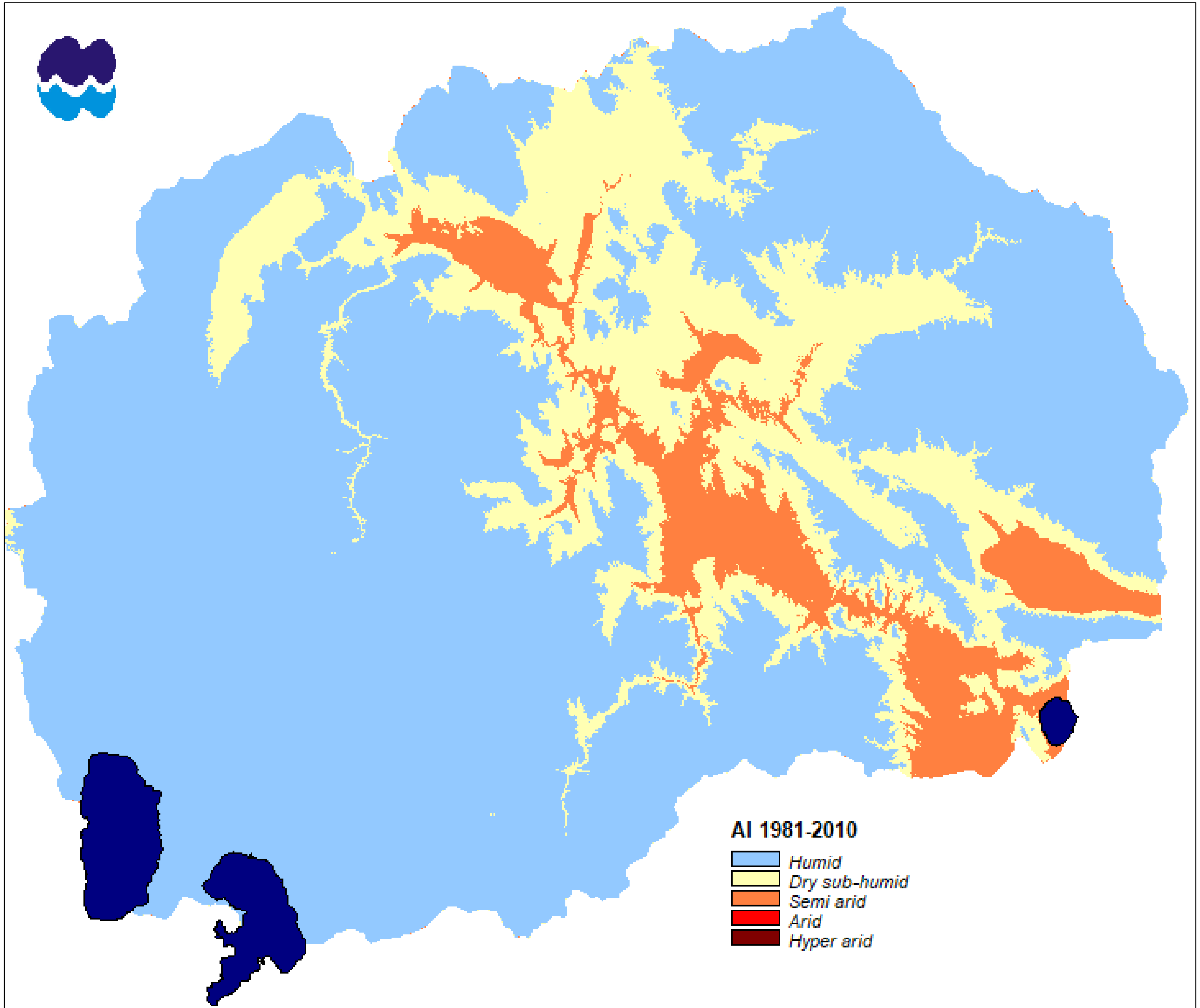






Aridity index for N.Macedonia (1981-2010)

- Humid 72%
- Dry sub humid 20%
- Semi arid 8 %



Drought vulnerability

The drought vulnerability map of RNM was prepared according to recommended procedure within the project "Drought Management Centre for South East Europe" (DMCSEE-OMSZ, 2011).

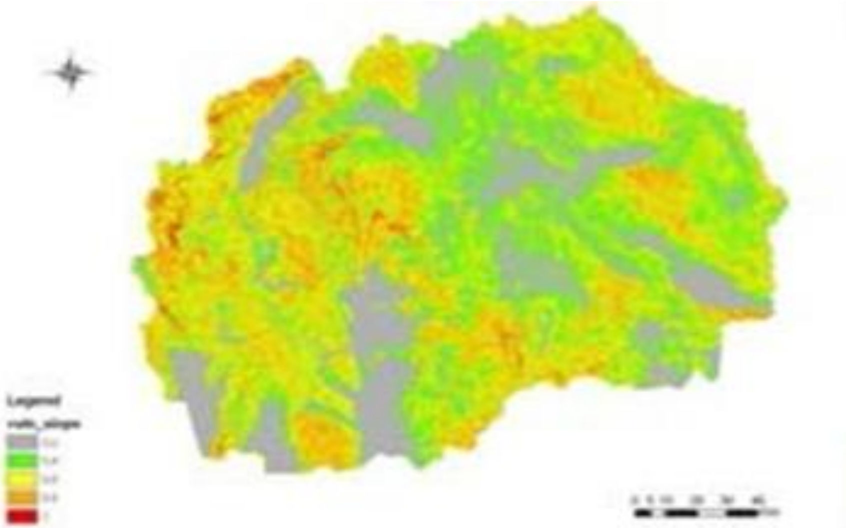
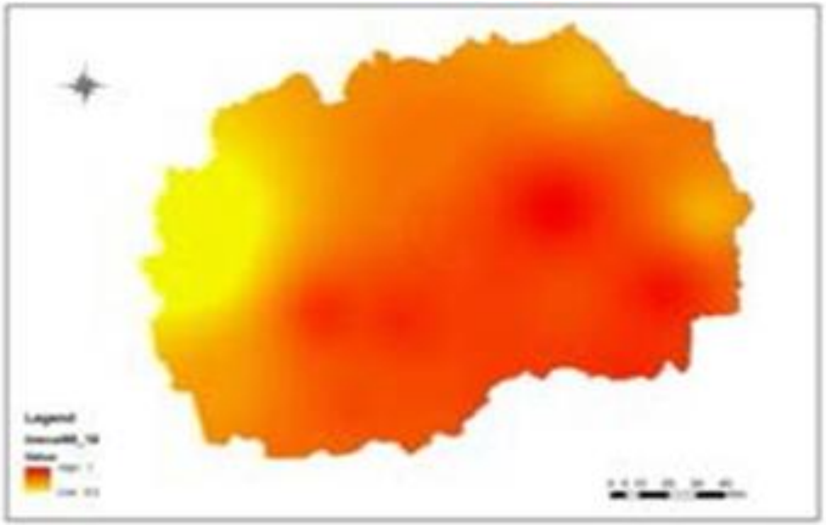
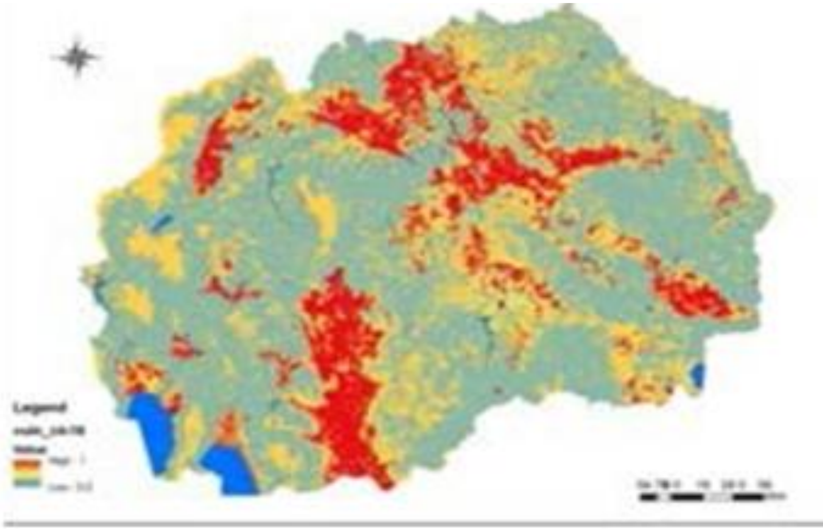
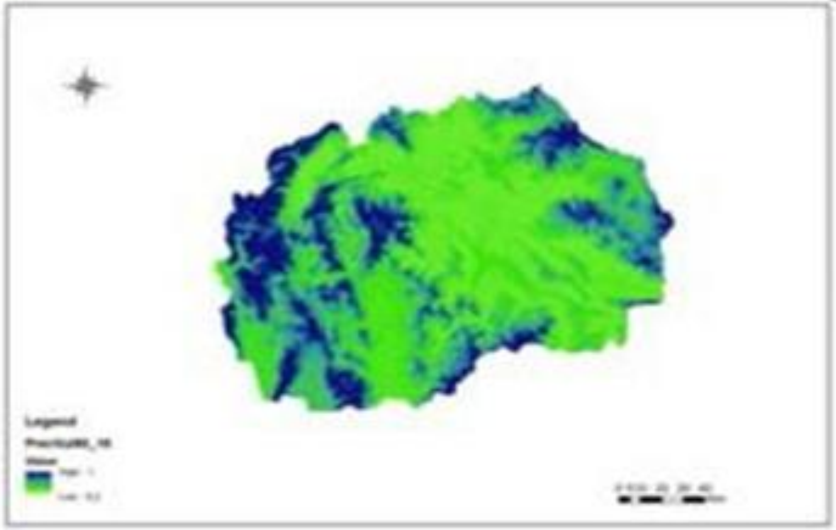
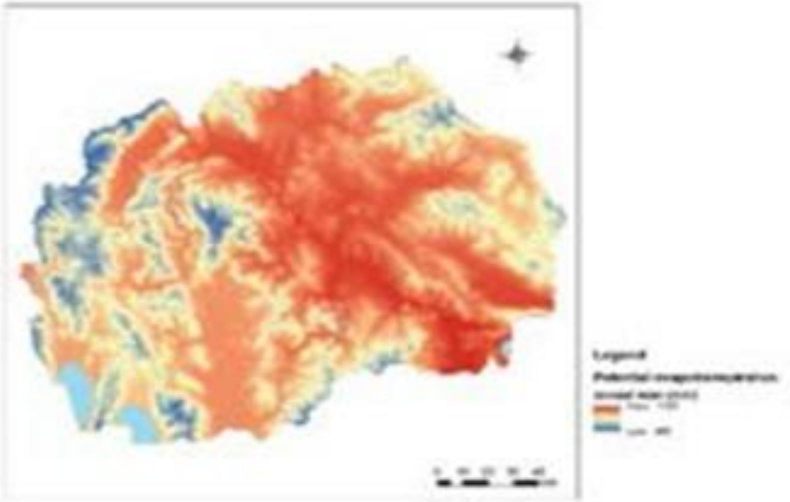
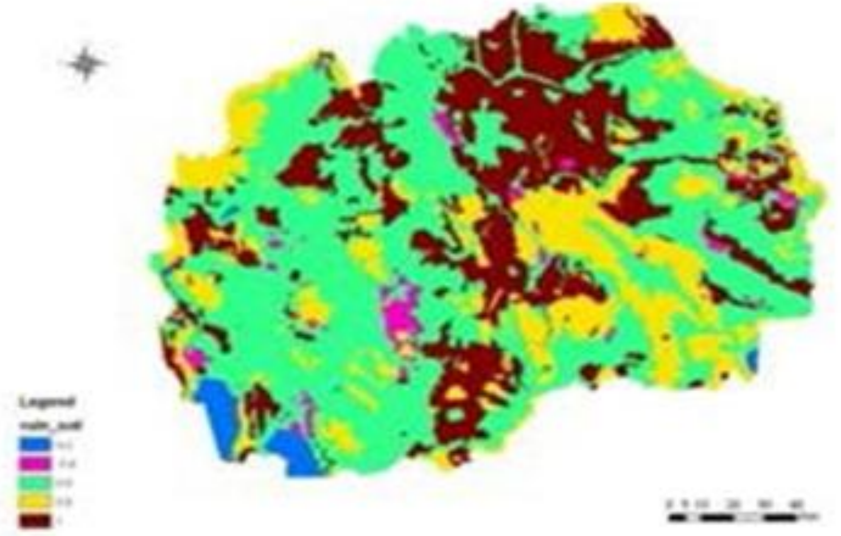
According to this methodology, the drought vulnerability map is calculated from category maps which are made of different selected parameters.
The development of the vulnerability map was developed in multi-criteria GIS environment.

Necessary parameters:

- ✓ **Slope angle**
- ✓ **Sunshine duration OR global radiation - in the vegetation period**
- ✓ **Precipitation – the ratio of the mean of the annual precipitation and the standard deviation (as ratio that characterizes the extremity of precipitation)**

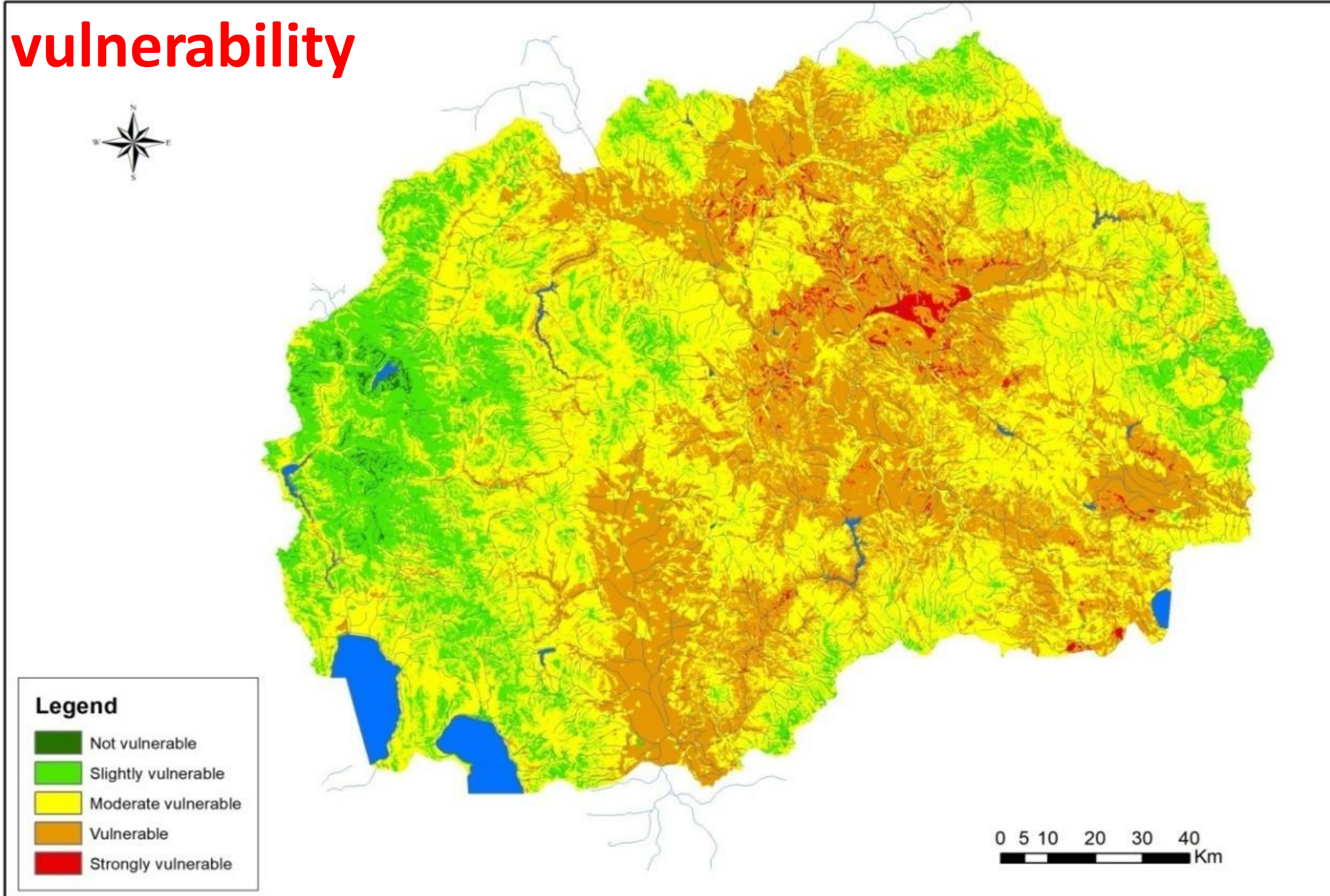
Optional parameters:

- ✓ **Land use,**
- ✓ **Soil type,**
- ✓ **Evapotranspiration.**

>>>>> multi-criteria modelling >>>

Drought vulnerability map



EROSION

2 methods were used

- **RRUSLE (Revised Universal Soil Loss Equation) - for the agricultural land**
- **EPM (Erosion Potential Method) – on national level, for watershed management and calculation on a basin level**

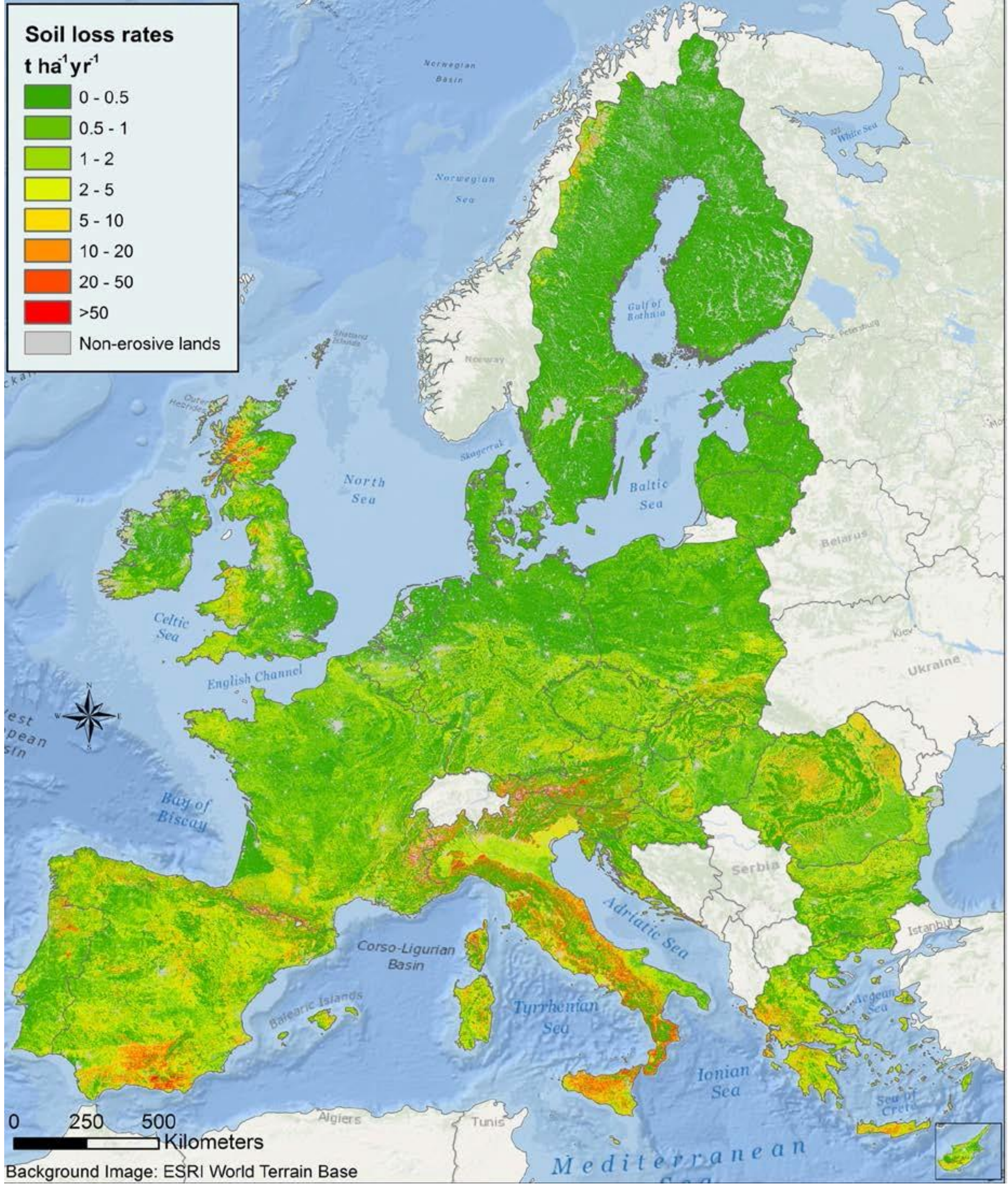
Erosion modelling using RUSLE

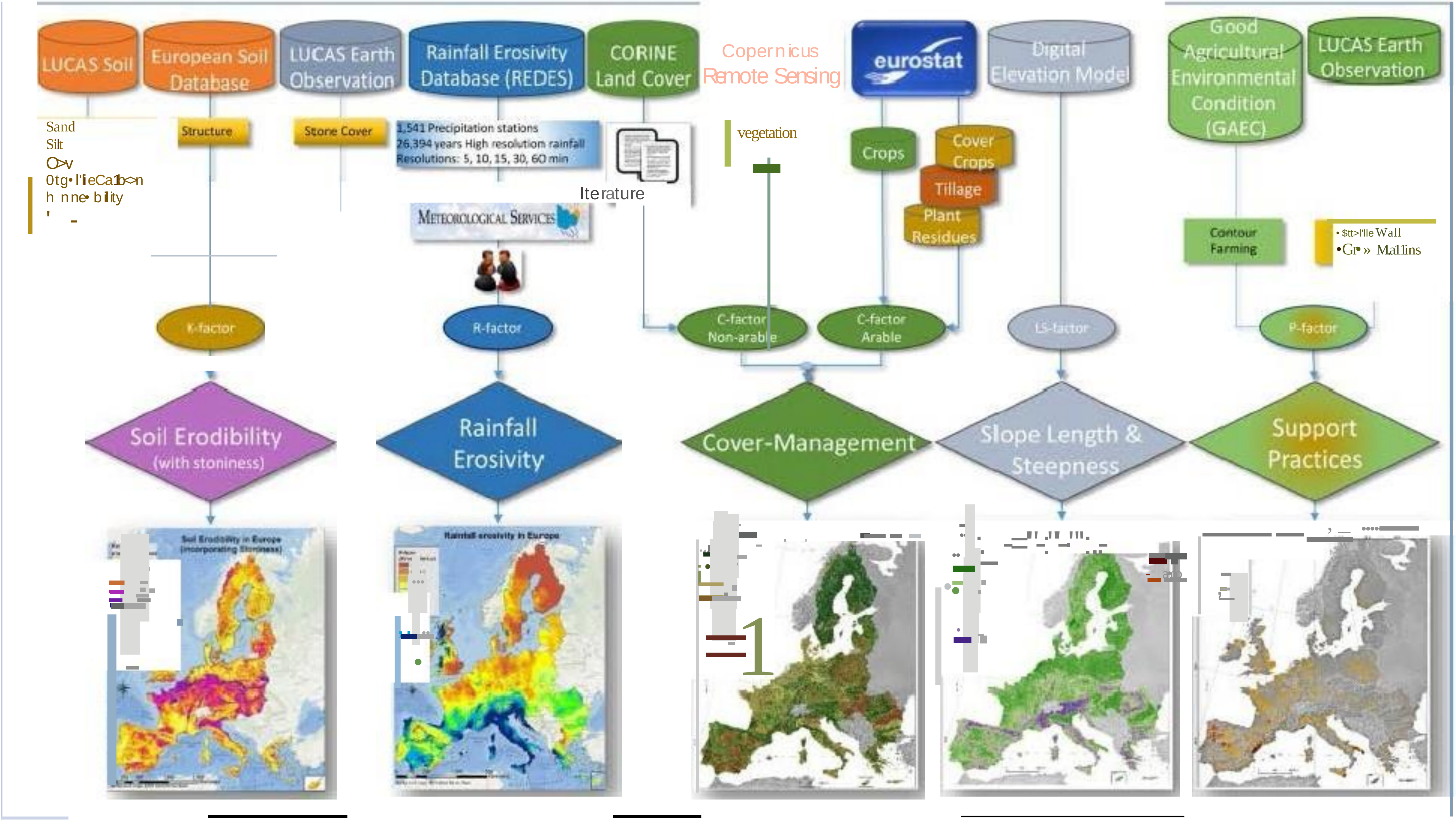
- The basic equation of USLE (RUSLE) is:

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

- *E* - annual average soil loss (t ha^{-1} yr^{-1}),
- *R* - rainfall erosivity factor (MJ mm h ha^{-1} yr^{-1}),
- *K* - soil erodibility factor (t ha^{-1} MJ^{-1} mm^{-1}),
- *C* - cover-management factor (dimensionless),
- LS - slope length and slope steepness factor (dimensionless), and
- *P* - support practices factor (dimensionless).

Approach by Panagos et al (2014,2015)

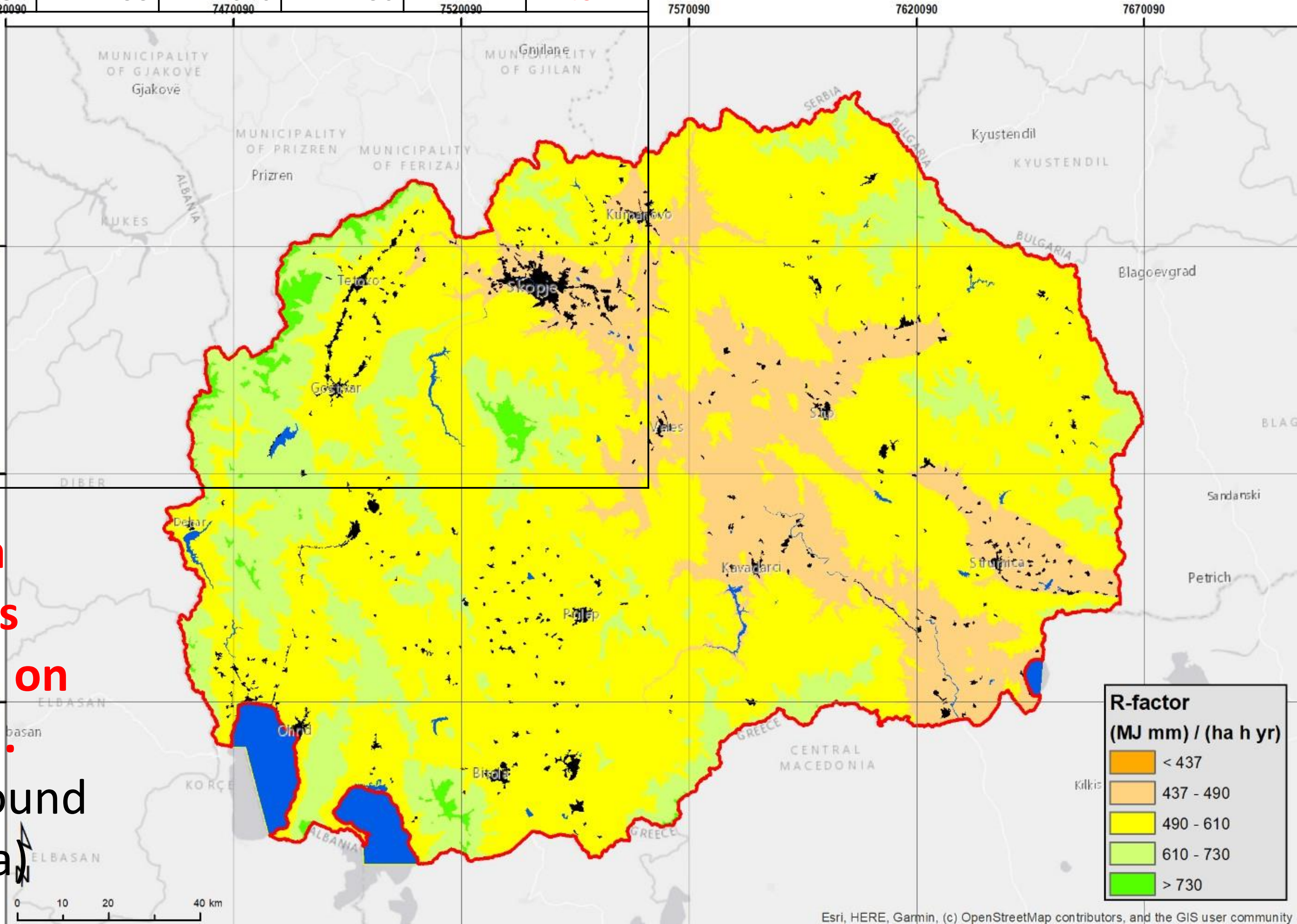




LUCAS Soil
European Soil Database
LUCAS Earth Observation
Rainfall Erosivity Database (REDES)
CORINE Land Cover
Copernicus Remote Sensing
eurostat
Digital Elevation Model
Good Agricultural Environmental Condition (GAEC)
LUCAS Earth Observation
Sand
Silt
Structure
Stone Cover
1,541 Precipitation stations
26,394 years High resolution rainfall
Resolutions: 5, 10, 15, 30, 60 min
Literature
vegetation
Crops
Cover Crops
Tillage
Plant Residues
Meteorological Services
Contour Farming
K-factor
R-factor
C-factor Non-arable
C-factor Arable
LS-factor
P-factor
Soil Erodibility (with stoniness)
Rainfall Erosivity
Cover-Management
Slope Length & Steepness
Support Practices
Soil Erodibility in Europe (incorporating Stoniness)
Rainfall erosivity in Europe

R factor

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						
Berovo	*611,1*	*378,1*	794	311						
Bitola	*619,9*	*321,6*	806	316						
K. Palanka	*624,7*	*395*	812	319						
Gevgelija	*678,6*	*334,1*	882	349						
Ohrid	*689,9*	*335,6*	897	355						
N. Dojran	*700,0*	*393,5*	910	360						
S. Glava	*838,6*	*485,6*	1090	437						
Krusevo	*881,3*	*457,9*	1146	460						
P. Sapka	*883,4*	*530,1*	1148	461						
Mavrovo	*993,5*	*467,7*	1292	522						
Lazaropole	*1060,4*	*504,6*	1379	559						

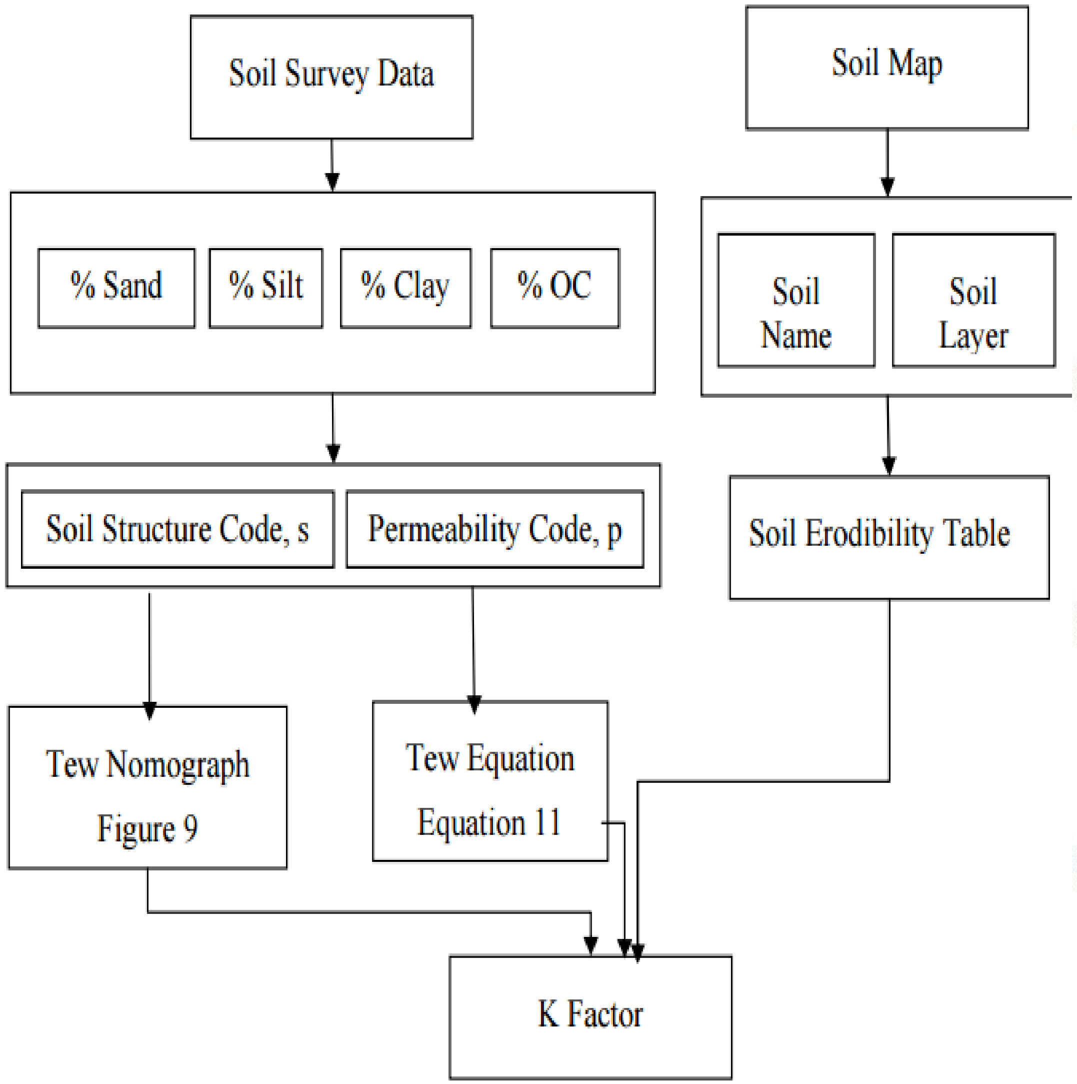


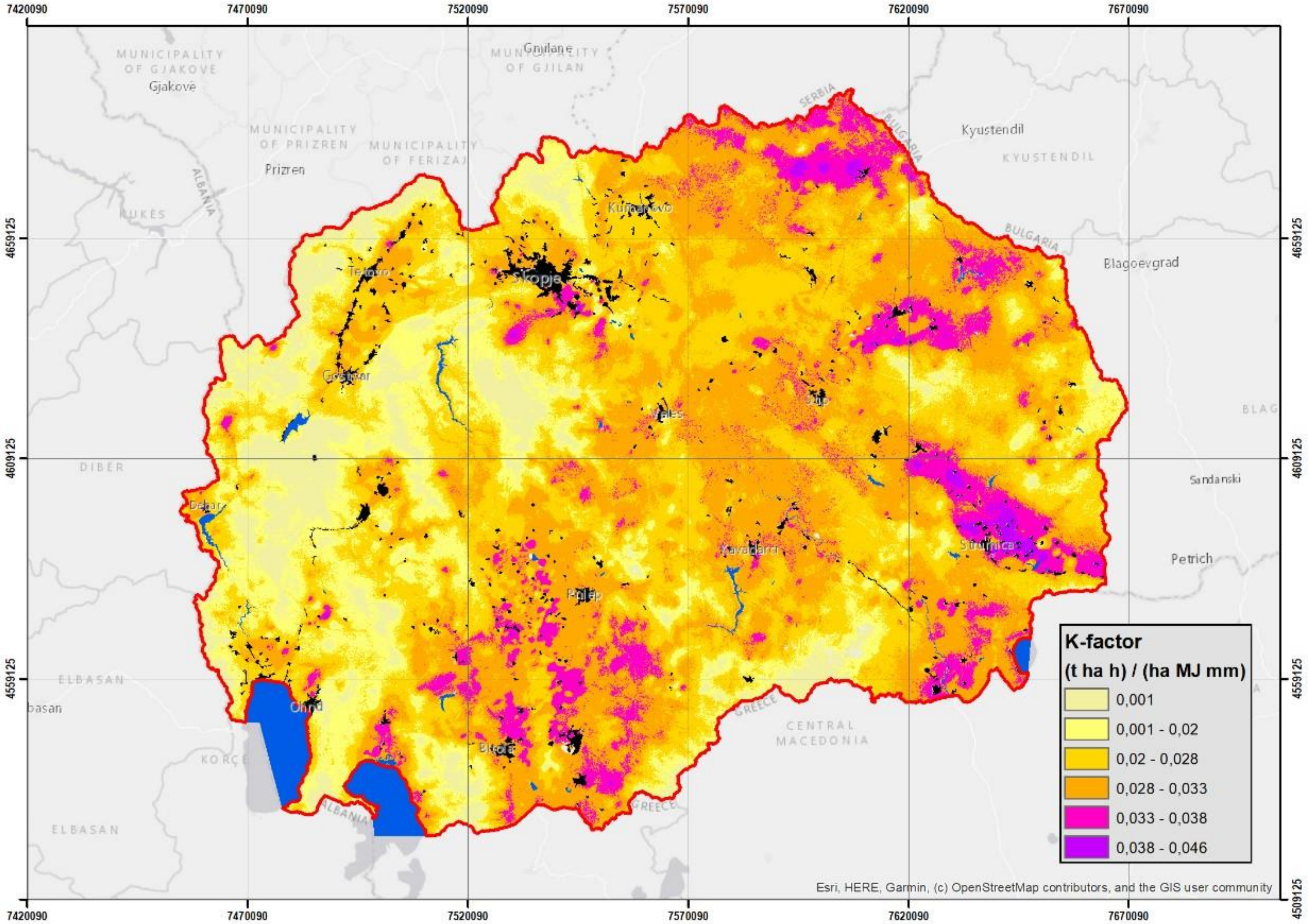
Because of absence of needed data (intensive rainfalls in mm/min) was developed original approach based on a total annual sum of precipitation .

Results were compared to those around the border with Greece and Bulgaria.

K – factor

$$K = \{[2.1 \times 10^{-4} * M^{1.14} * (12 - OM) + 3.25(s-2) + 2{,}5(p-3)]/100]\} * 0.1317$$

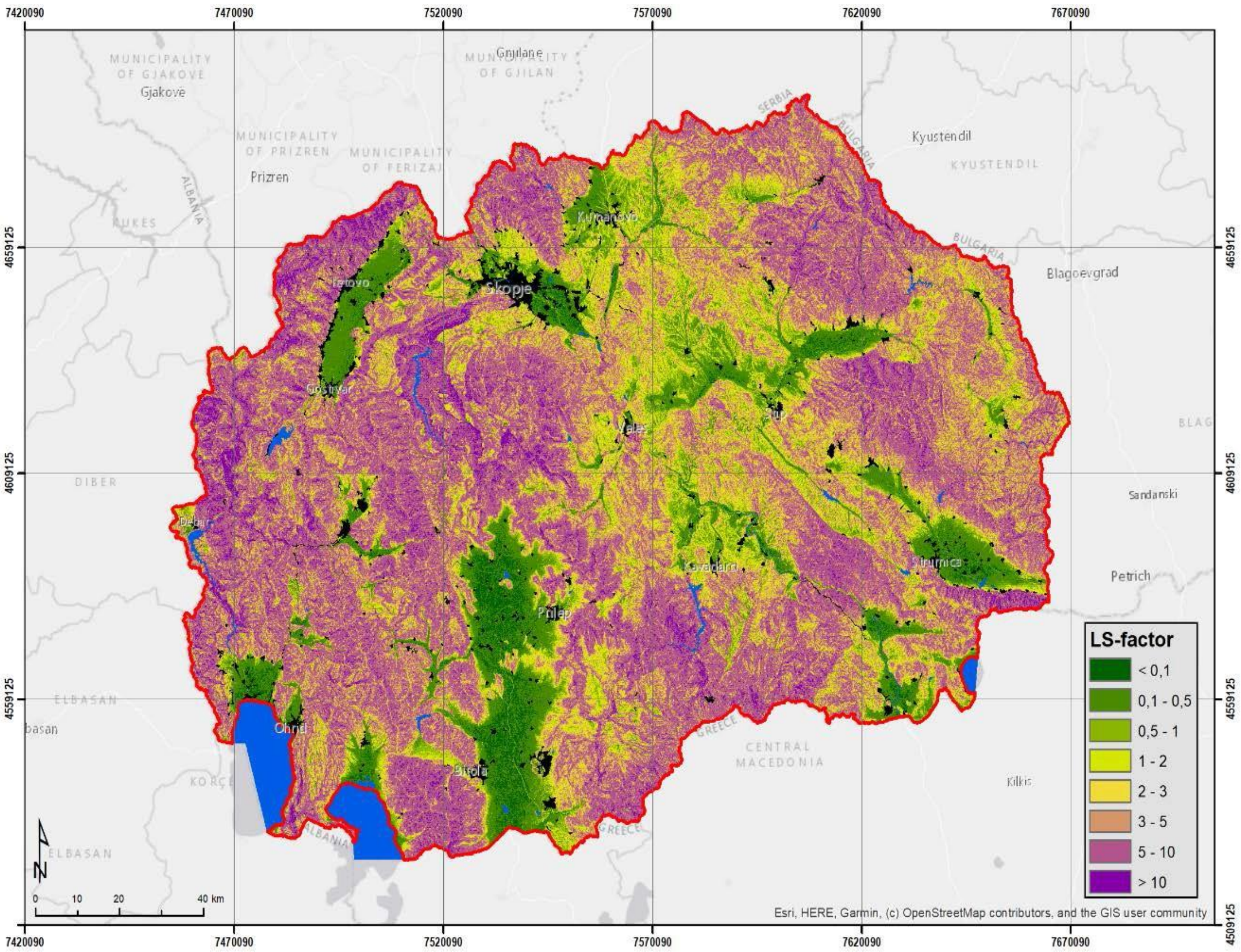




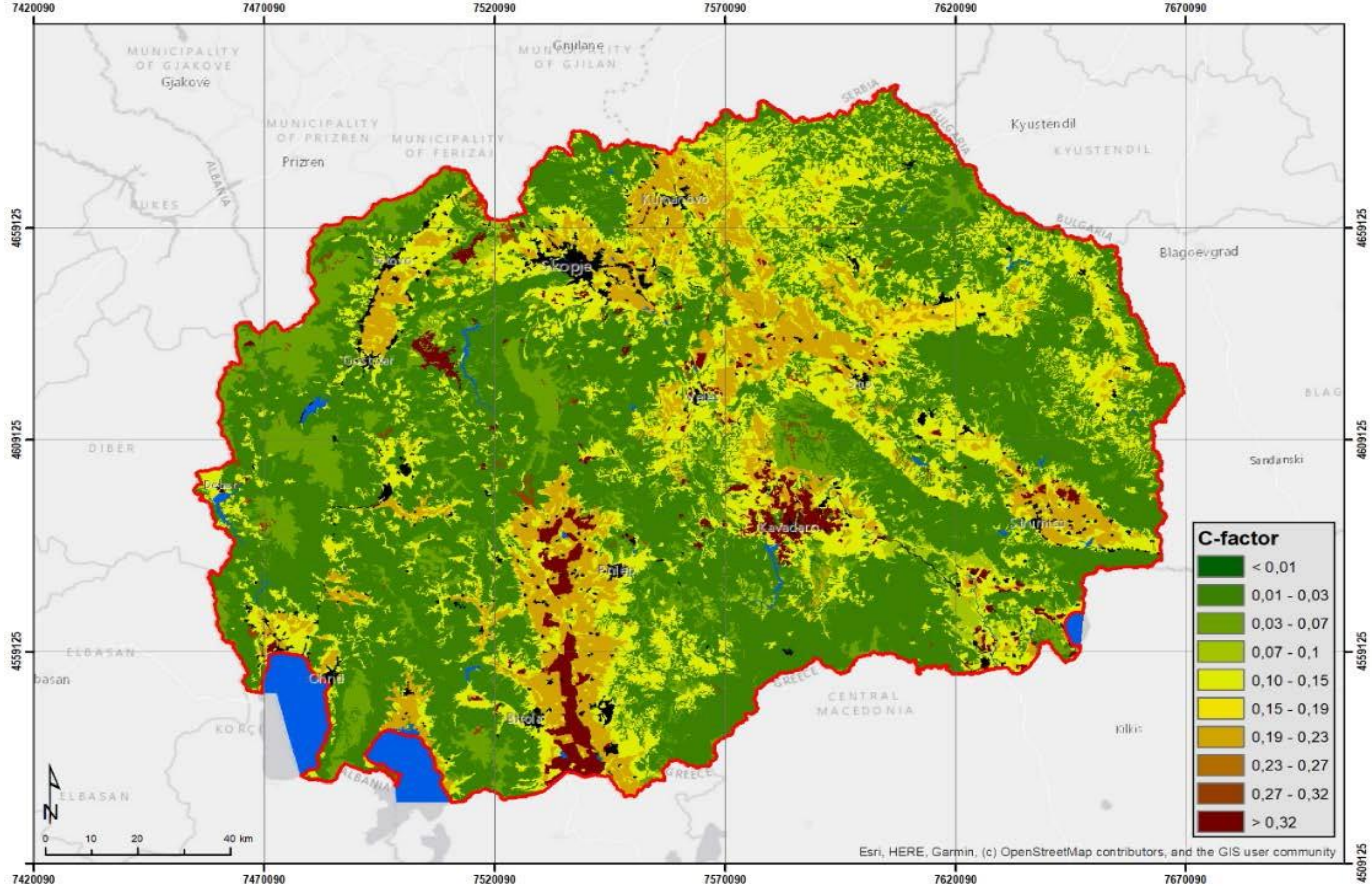
LS factor

$$L_{i,j} = \frac{(A_{i,j-in} + D^2)^{m+1} - A_{i,j-in}^{m+1}}{D^{m+2} * x_{i,j}^{m} * 22.13^{m}}$$

$$m = \frac{\beta}{\beta+1} \qquad \beta = \frac{\frac{\sin\theta}{0.0896}}{[0.56 + 3*(\sin\theta)^{0.8}]}$$

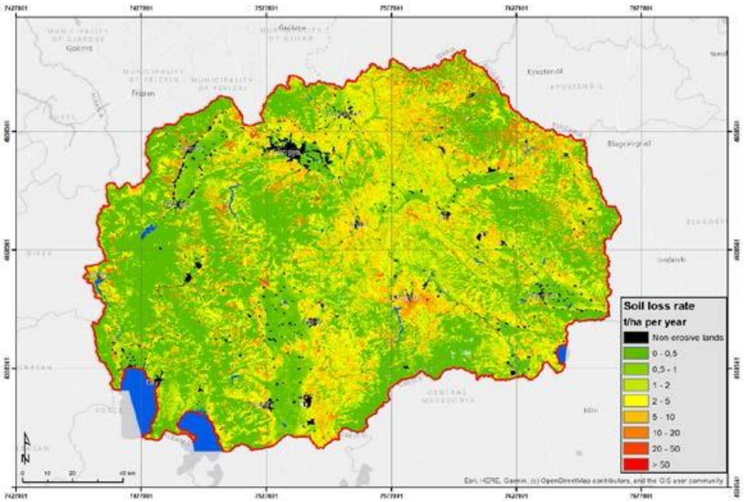


C - Factor



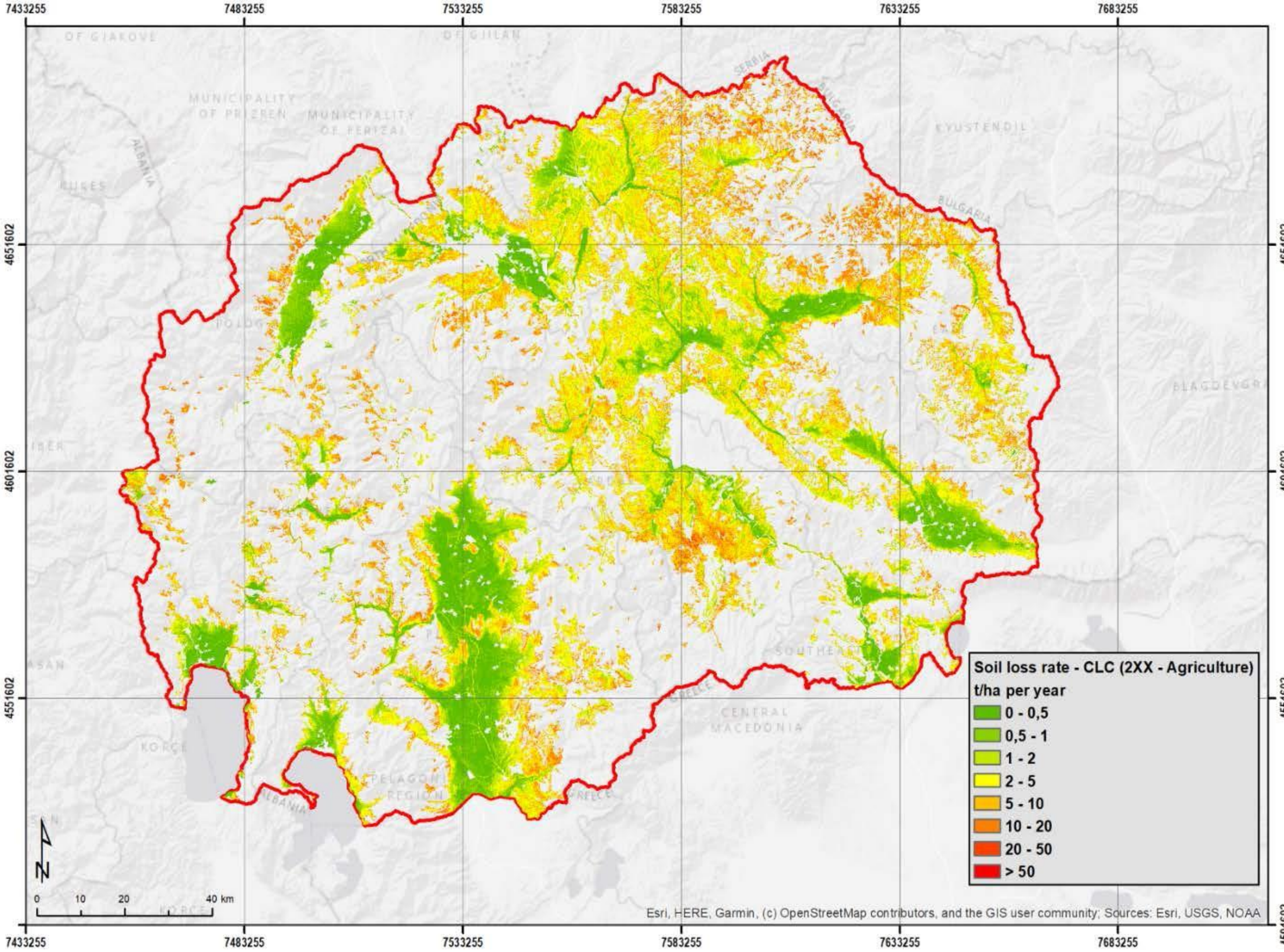
7420090
7470090
7520090
7570090
7620090
7670090
4659125
4609125
4559125
4509125
C-factor
< 0,01
0,01 - 0,03
0,03 - 0,07
0,07 - 0,1
0,10 - 0,15
0,15 - 0,19
0,19 - 0,23
0,23 - 0,27
0,27 - 0,32
> 0,32
0 10 20 40 km
Esri, HERE, Garmin, (c) OpenStreetMap contributors, and the GIS user community
Skopje
Kumanovo
Kavadarci
Gjakove
Prizren
Kyustendil
Blagoevgrad
Sandanski

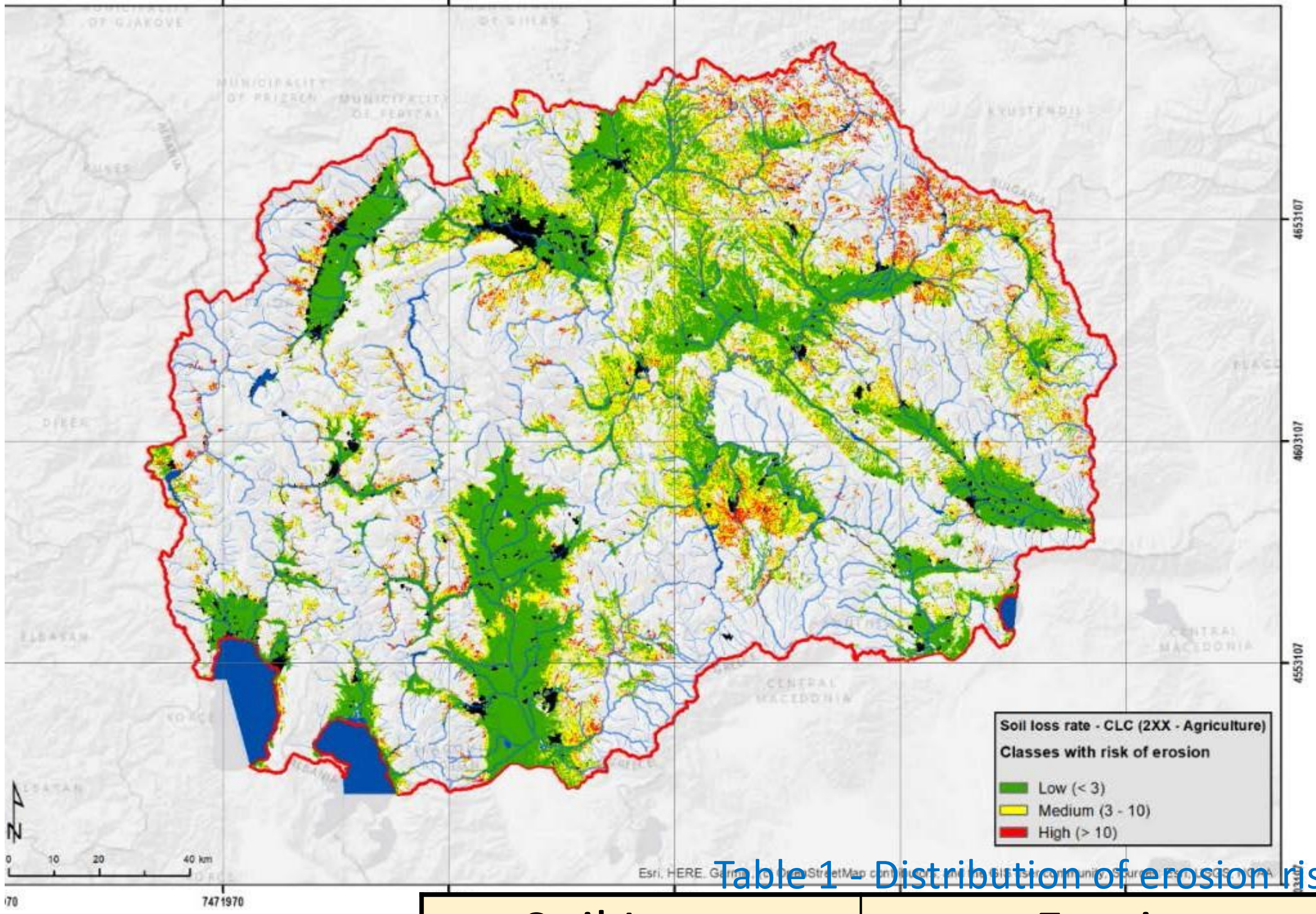
Calculation of E – mean annual soil losses – RRUSLE



- Mean value nationa
value is E = 4,11 t/ha, anc
vary from 0 – 69 t/ha

The highest soil losses are located in the areas classified as land principally occupied by agriculture with significant areas of natural vegetation, located in mountainous region





High risk Erosion areas on agricultural land - by RRUSLE

Table 1 – Distribution of erosion risk classes on agricultural land

Soil Loss [t/ha]	Erosion processes	Area [ha]	Area [%]
< 3	low	477.154,75	52,7
3 - 10	Medium to high	340.935,00	37,6
> 10	High and very high	880,25	9,7

Erosion modelling using EPM by Gavrilovic

There are two approaches for defining Z – coefficient:

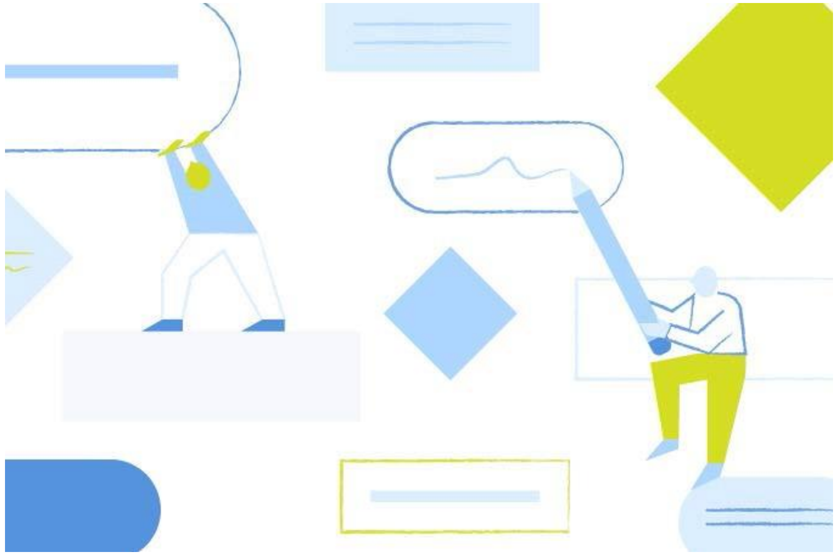
- through direct on-field mapping and
- through calculation of Z

Degr. Categ.	Erosion porcesses	Eros. intensity (m^3 km^2 y^{-1})	Z coefficient	
			From - to	avg
I	Very high	> 3000	0,91-1,50+	1,25
II	High	1500 – 3000	0,71-0,90	0,85
III	Moderate	1000 – 1500	0,41-0,70	0,55
IV	Low	500 – 1000	0,20 – 0,40	0,30
V	Very low	70 – 500	<0,19	0,10

General methodology approach for EPM modelling

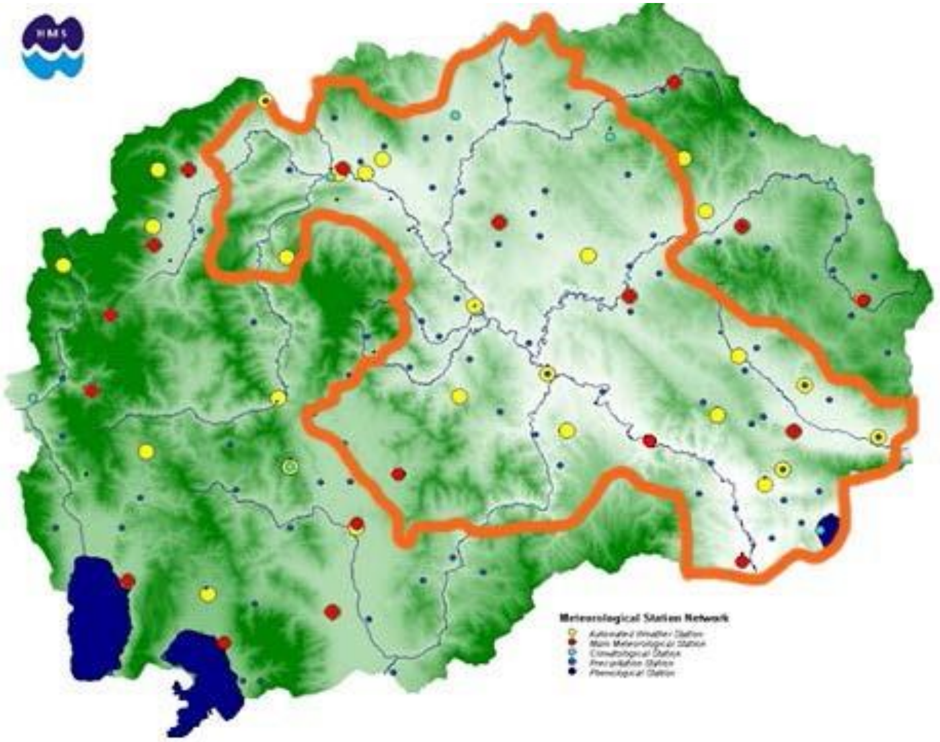
This work is consisted of few phases as follow:

- Preliminary desk-top work,
- Collecting necessary data,
- Collecting field data (mapping φ and Z using expert judgment approach for control),
- Preparation of a database in a GIS environment,
- Modelling
- Field validation of the results.



Field trip

- **Tetovo (upper part of Polog valey and Suva Gora),**
- **Skopje (Radusa to Matka, Skopska Crna Gora, Vodno – Sonje up to dam Sv. Petka and Kozjak, eastern part up to Arachinovo, Ilinden Konjari and Petrovec),**
- **Kumanovo (the Pcinja basin, and up to Skackovce and Stracin),**
- **Stracin - Rankovce - Kratovo,**
- **Skopje - Veles,**
- **Chashka – Izvor - Bogomila,**
- **Sveti Nikole (north and south) , Veles –Sveti Nikole, Mialdinovc Sv.Nikole, Mavrovica and Lisiche reservoir basin,**
- **Stip – Karbinci,**
- **Krivolak,**
- **Gradsko - Negotino (both sides of Vardar river),**
- **Kavadarci (up to the hilly mountain region and part of Crna Rek gorge),**
- **Radovis – Strumica region,**
- **Valandovo – Dojran,**
- **Miravci – Gevgelija.**



Selected Photos from field trips

Formula for Z-calculations - EPM

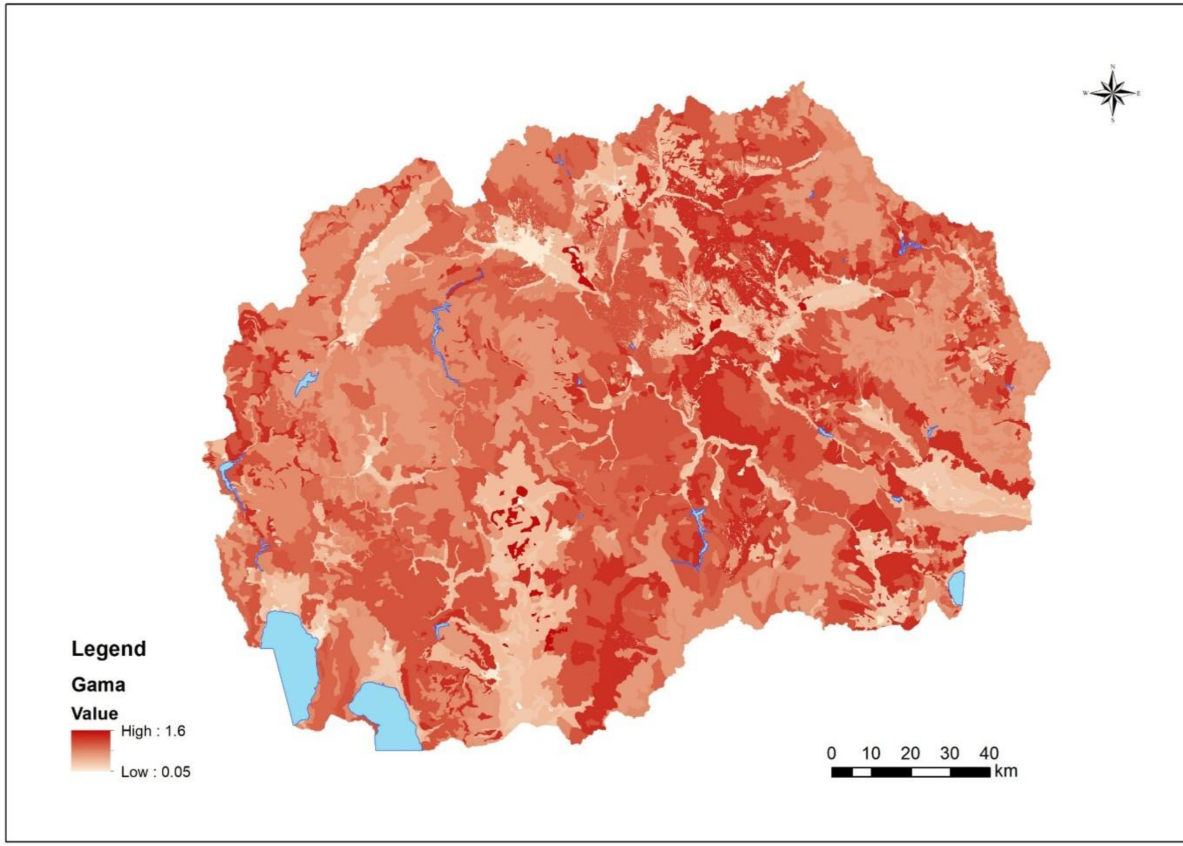
$$Z = \gamma * Xa * (\varphi + \sqrt{I_{sr}})$$

- $\boldsymbol{Z}$ – erosion coefficient by Gavrilovic
- $\boldsymbol{\gamma}$ **–** *reciprocal value of the coefficient of resistance of the soil to erosion (0,25< γ<2,00)*
- **Xa** – coefficient of regulation of the basin and it takes in consideration the level of protection of the and from erosive forces in natural conditions (X) and artificial conditions (a) (0.01<Xa<1.00).
- $\boldsymbol{\varphi}$ - numerical equivalent of visible and clearly articulated process of erosion in the watershed
- $\mathbf{I_{sr}}$ – *average slope of the watershed expressed in decimal* value

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

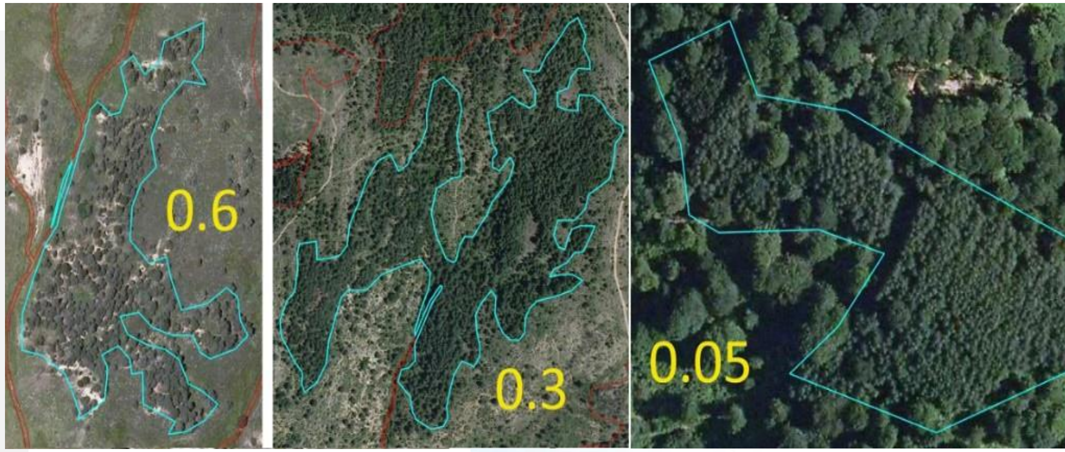
(changes in the table with aim to be in accordance with current soil classification)

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



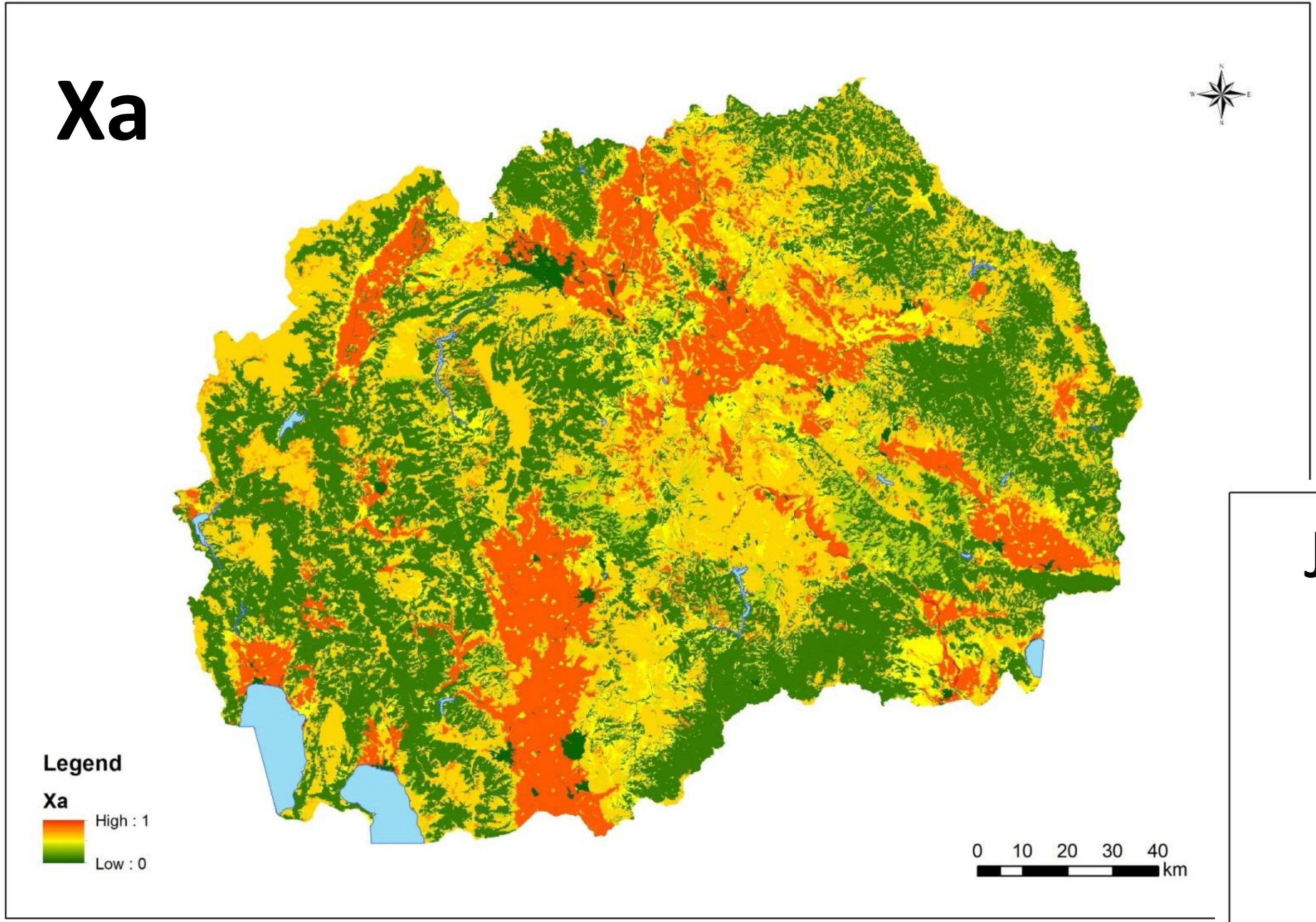
Xa – coefficient of protection of the basin/area and it takes in consideration the level of protection of the and from erosive forces in natural conditions (X) and artificial conditions (a) (*changes in the table because CORINELCU is not enough precise)*

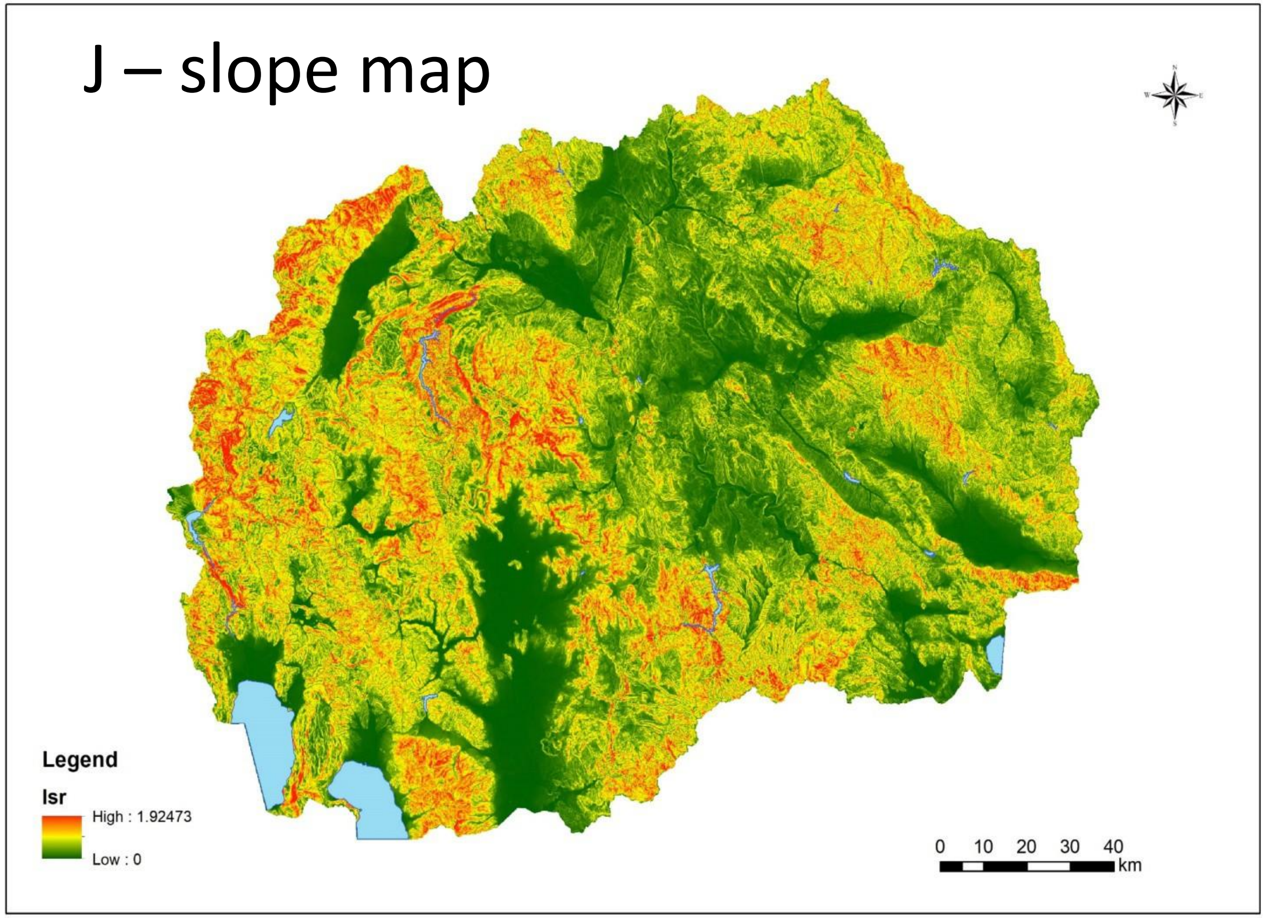
N0	Conditions that affect the value of the coefficient X and a	Mean value		
		X	**a**	**X.a**
I River basin or area before undertaking anti-erosion works and measures				
1	Open spaces with little or no vegetation (*Completely bare, untilled land) and mined, dump and construction cites*	1,0	1,0	1,0
2	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



al zone is classified as 321- natural grassland or 324 – sitional woodland and shrubs. In fact, this area is bare

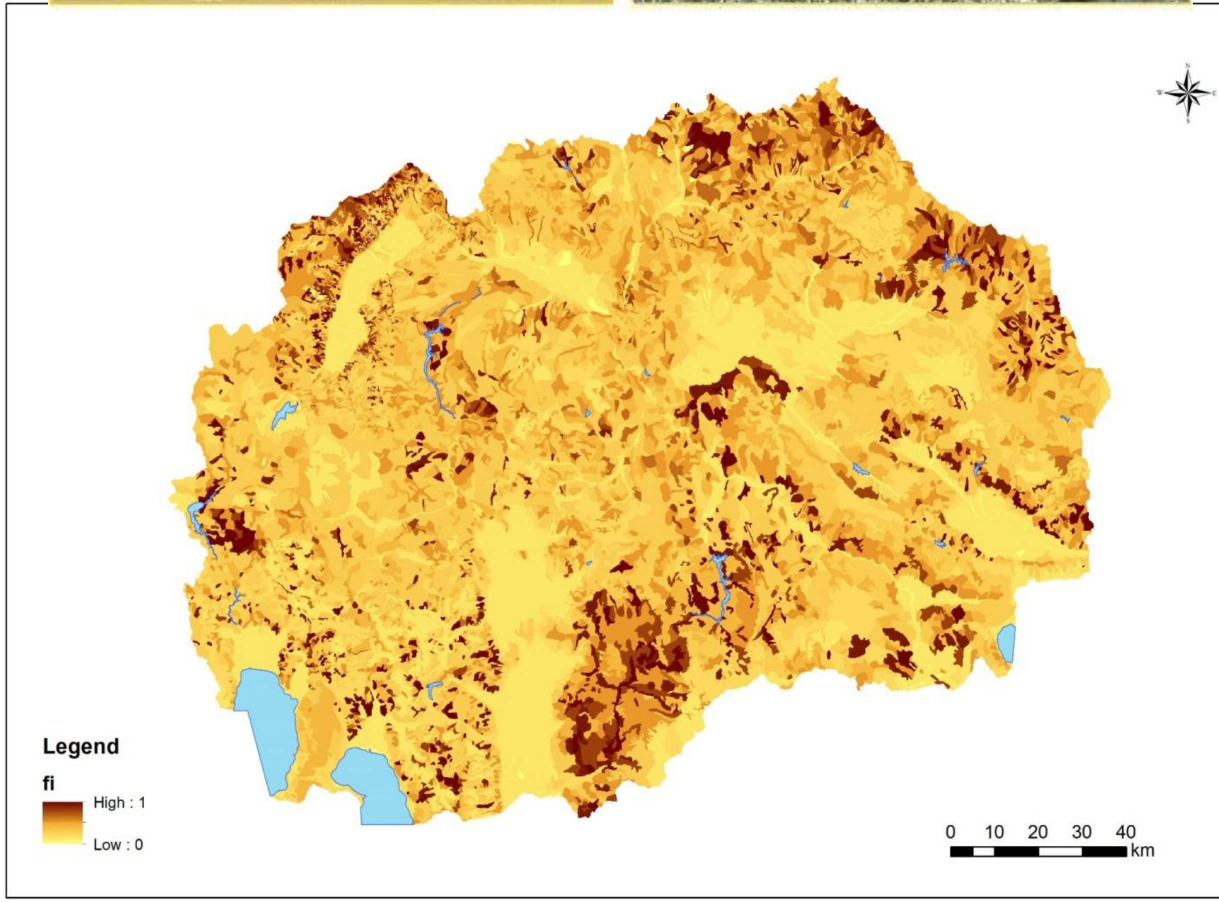
and erosion processes are significant.


Xa
Legend
Xa
High : 1
Low : 0
0 10 20 30 40
km

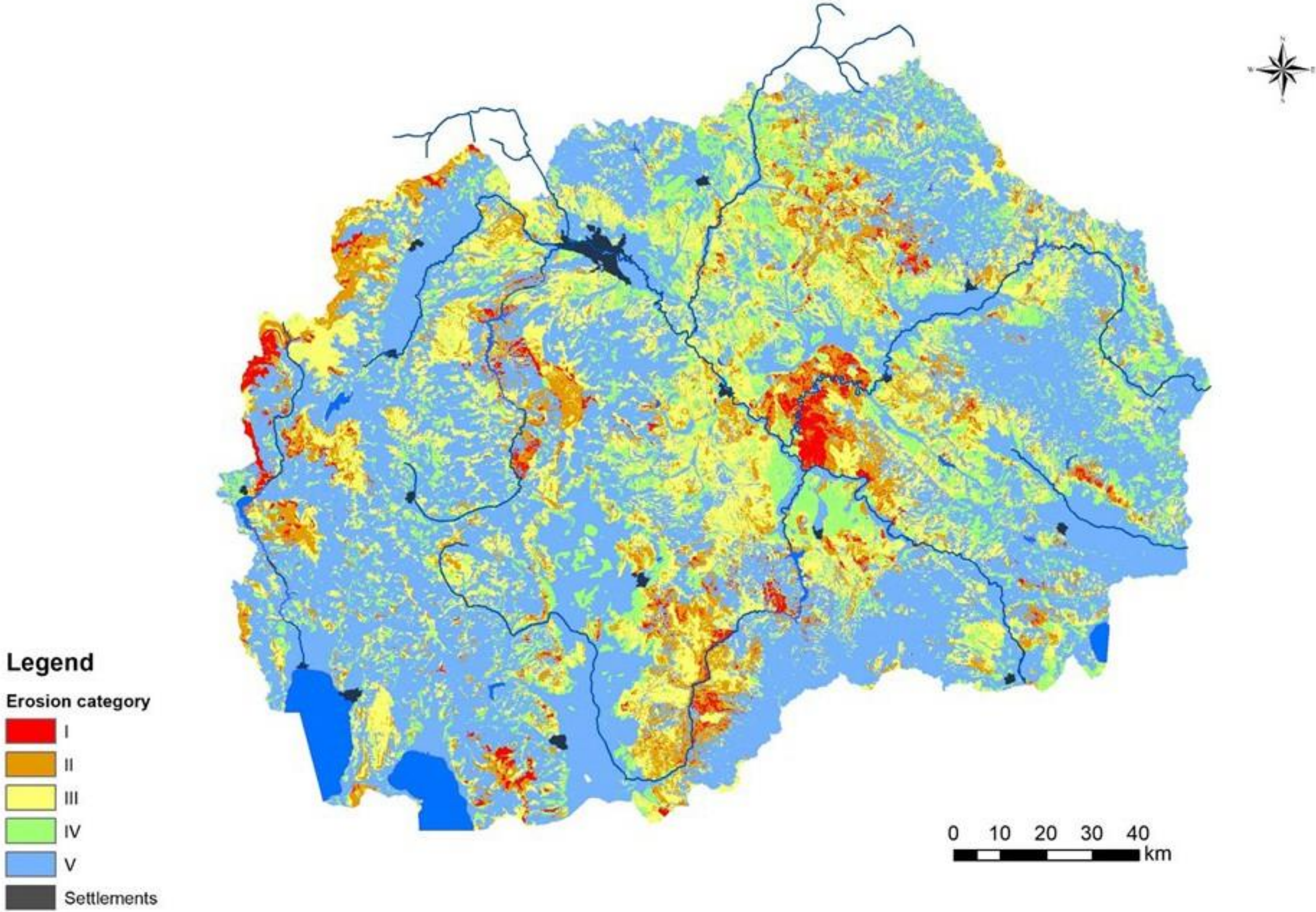

J – slope map
Legend
Isr
High : 1.92473
Low : 0
0 10 20 30 40
km

Values of – φ– coefficient

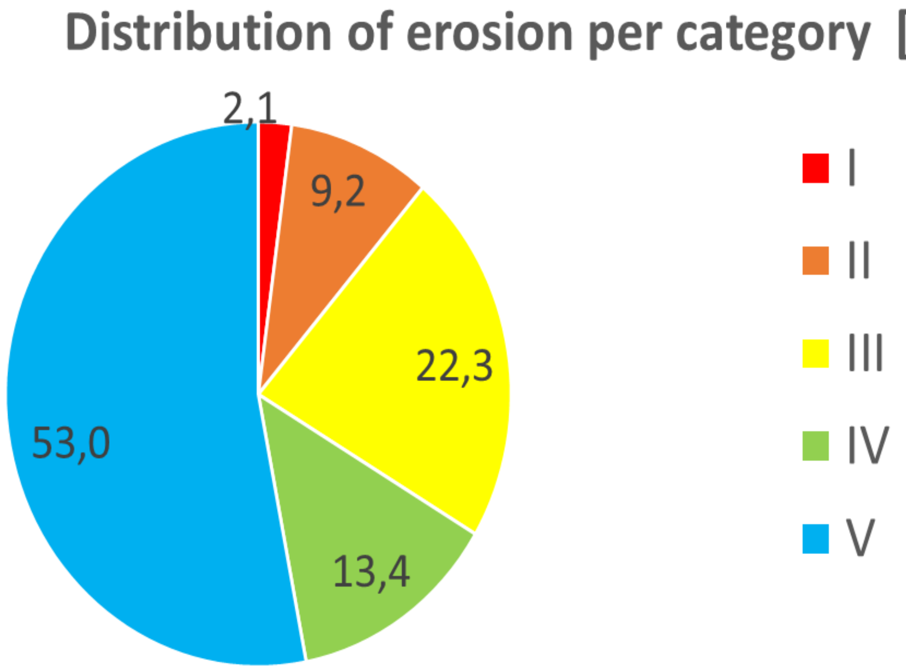
No	Conditions that affect the value of the coefficient	φ
1.	Watershed or area fully occupied by rill, inter-rill erosion and gully processes (deep erosion)	1,00
2.	About 80% of the watershed or area is under rill and inter-rill erosion processes	0,90
3.	About 50% of the watershed or area is under rill or inter-rill erosion processes	0,80
4.	The entire watershed or area is under surface erosionprocesses and there is retail presence of grooves and rill and inter-rill forms (deep erosion processes) as well as strong karst erosion processes	0,70
5.	The watershed or area is under the surface erosion processes, but there are no visible deep erosion processes (rill, inter-rill forms, landslides, etc.).	0,60
6.	50% of the area is under the surface erosion processes, and the other part of the watershed is preserved	0,50
7.	20% of the area is under surface erosion processes and the rest is preserved	0,30
8.	There are are no visible traces of erosion on the areas in the watershed, but in the riverbeds there are small landslides and rockfalls	0,20
9.	The watershed is with no visible trace of erosion processes but mostly is under under the crop fields	0,15
10.	The watershed and the riverbeds are with no visible traces of erosion, but usually those areas are under forests, meadows, pastures, etc.	0,10



EROSION MAP

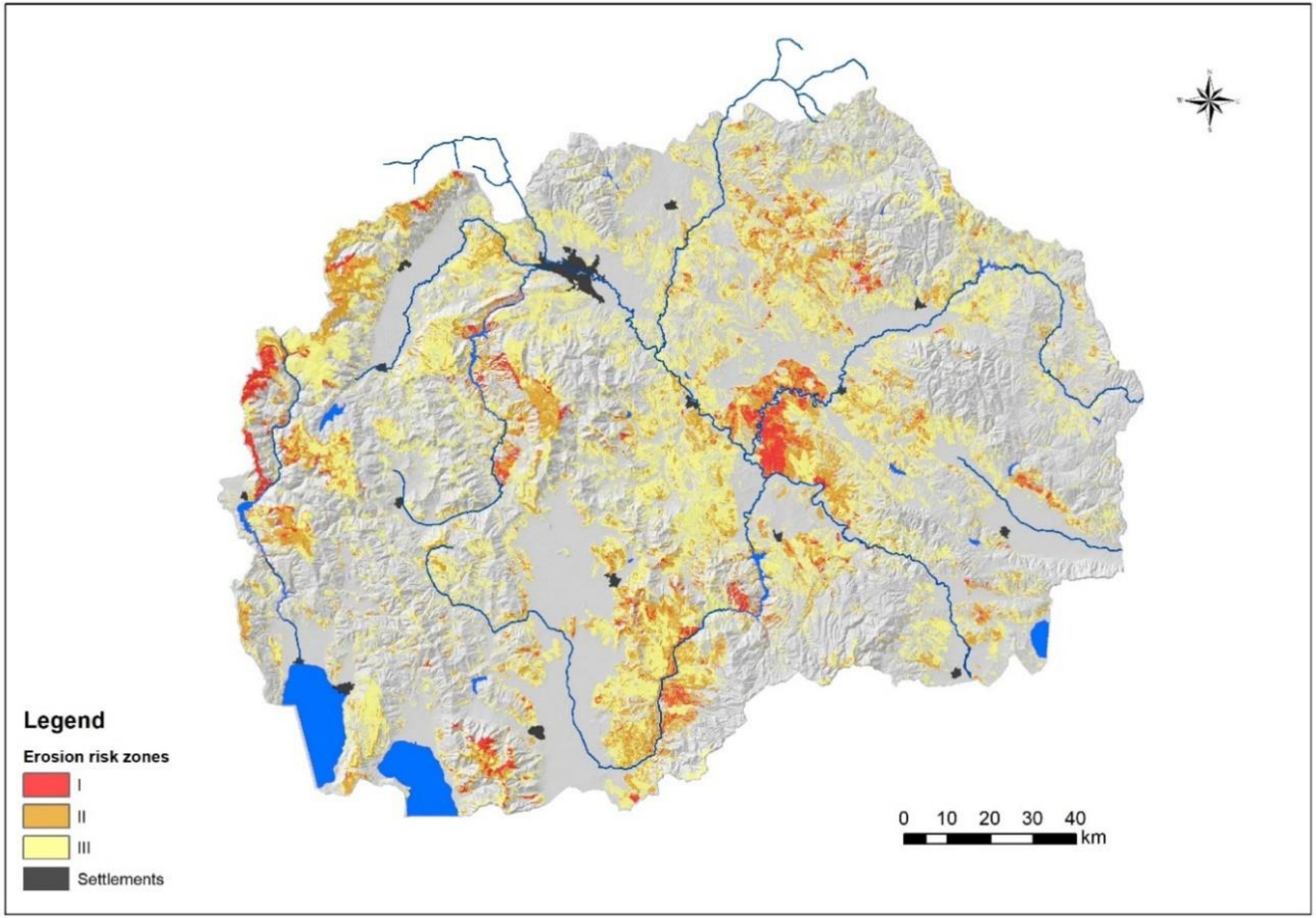

Legend
Erosion category
I
II
III
IV
V
Settlements
0 10 20 30 40
km

Category of erosion		Z - value	Area (ha)	%
I	Very High	1.25	52651	2,1
II	High	0.85	227675	9,2
III	Medium	0.55	553804	22,3
IV	Low	0.3	332850	13,4
V	Very Low	0.1	1317682	53,0



Note: Z – values in the western part of the country could be higher because of terrain configuration. These terrains characterize with significantly developed drainage net, where fluvial erosion and torrent bank collapse are usual and there are processes of rock weathering on very steep almost vertical slopes, that significantly increase erosion intensity but these processes where Z value achieve >3 (during erosion mapping using expert judgment approach) cover small narrow polygon almost invisible on the map.

High -risk erosion areas (EPM)



- The highest three classes (I-III), cover 834.130 ha or 33,57 % of the land territory (area of lakes is excluded).
- The areas with high priority for erosion control (I and II erosion category) cover in total 280.326 ha or 11,3 % of the territory.

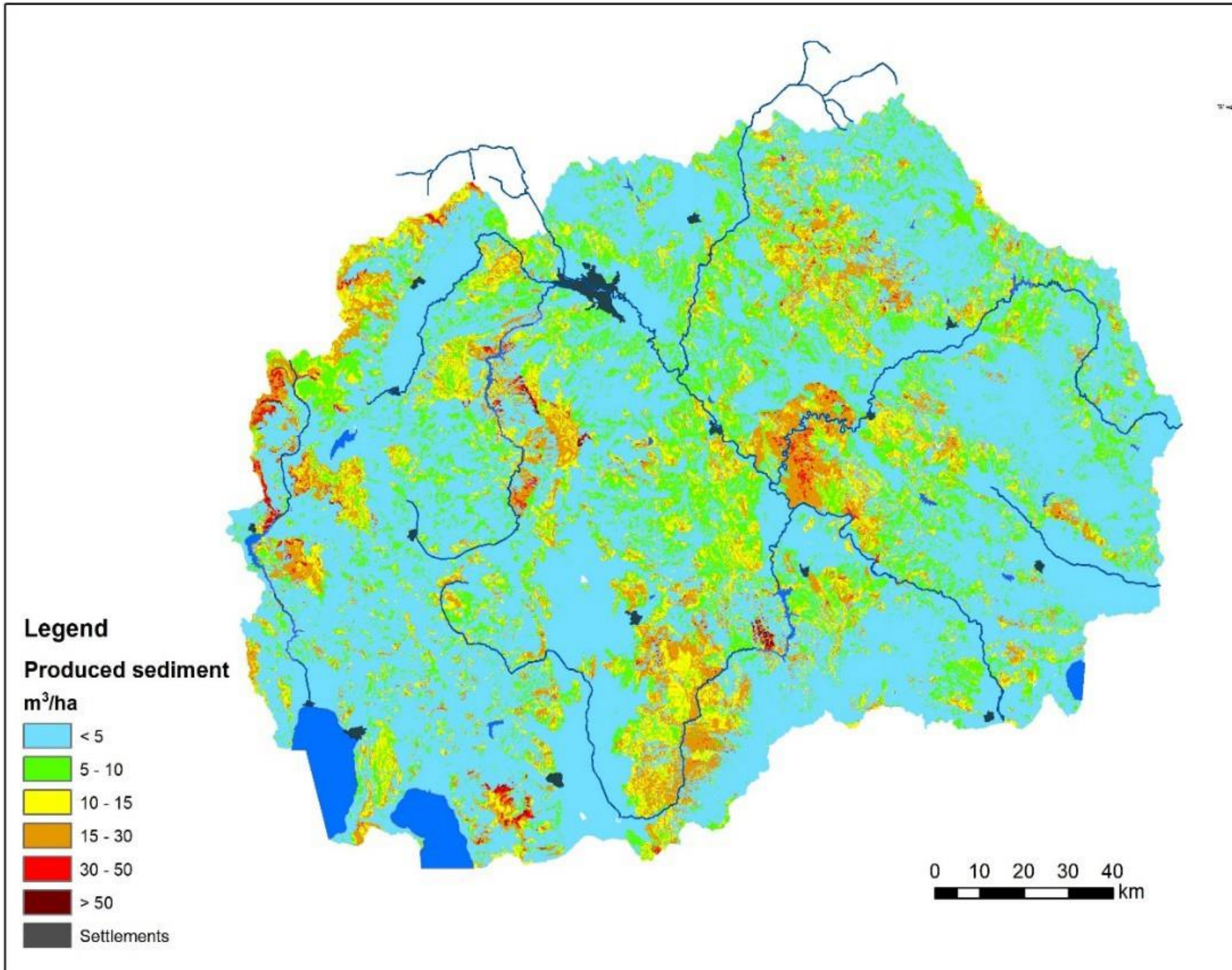
Calculation of Wsp – mean annual produced erosive material

$$Wsp = T \cdot H_{ann} \cdot \pi \cdot \sqrt{z^3}$$

- T – temperature coefficient

$$T = \sqrt{\frac{t_0 C}{10}} + 0{,}1$$

- t - mean annual temperature
- H_{ann} –mean annual precipitation [mm]
- Z – erosion coefficient
- W = 12.900.832 m^3
- **Wsp = 519 m^3/ km^2.**



According to Erosion Map using EPM, mean erosion coefficient on country level is Z = 0,31. About 33,6% of the country is affected by unacceptable intensity of erosion processes (I, II and III category), while 11,3% of the country is affected by high and very high erosion processes.

Based on this map total annual production of erosive material (sediment) is W = 12.900.832 m^3, or mean annual specific production Wsp = 519 m^3/ km^2.

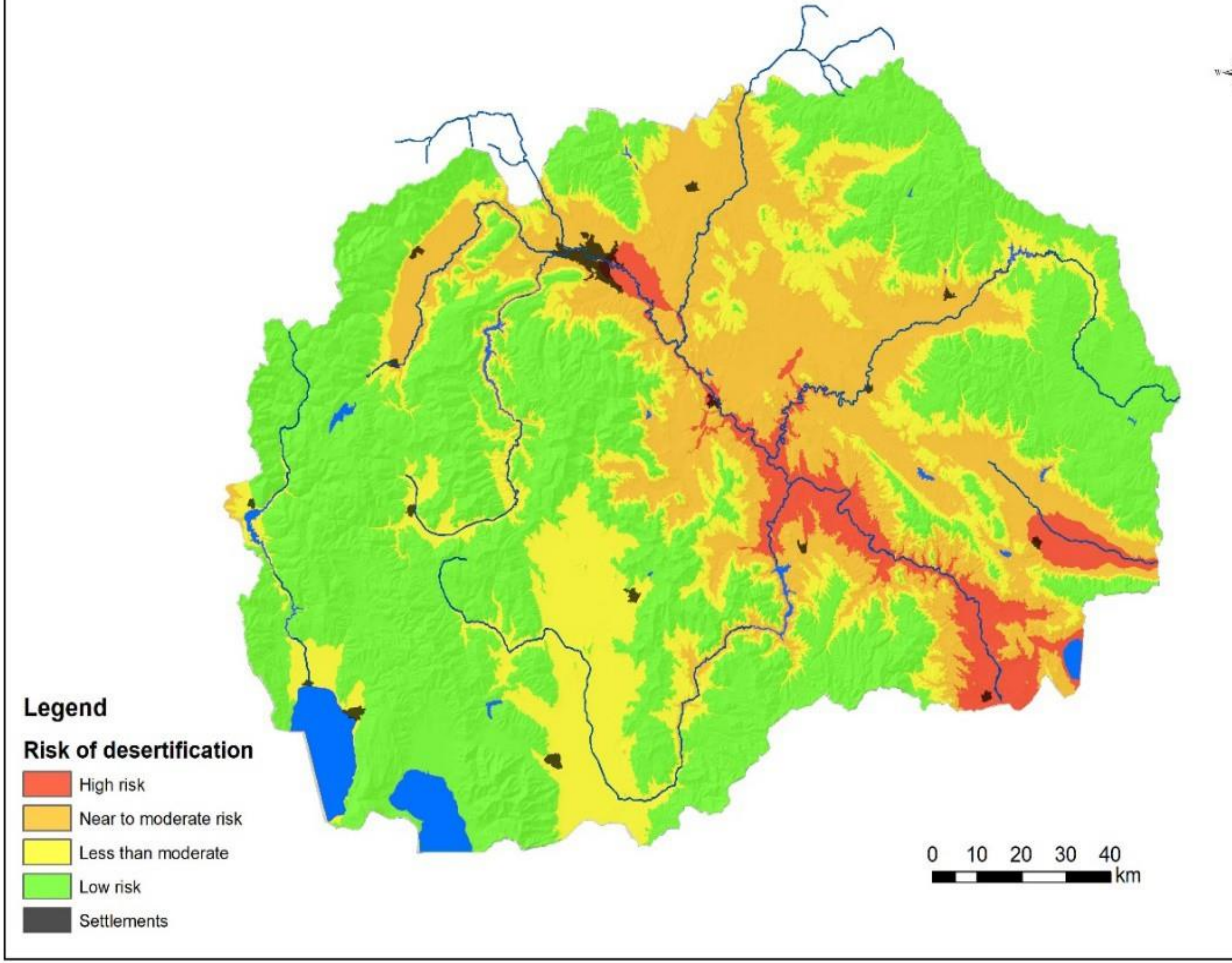
These values are lower than those acquired in the previous map prepared 30-40 years ago using direct on-field mapping using expert judgment opinion as Z = 0,33, W = 17.000.000 m^3 and Wsp = 685 m^3/ km^2.

From erosion point of view, situation is improved today because of several factors as follow: erosion control measures, decrease of rural population, land abandonment and overgrowth of this land with woody vegetation, improvement of agricultural practices, decrease of livestock.

But in the western part of the country these values will be higher because of “point” or “line” sources of sediments (rockfalls, landfalls, landslides, bank collapse… that are small for map scale but are significant source of sediments.

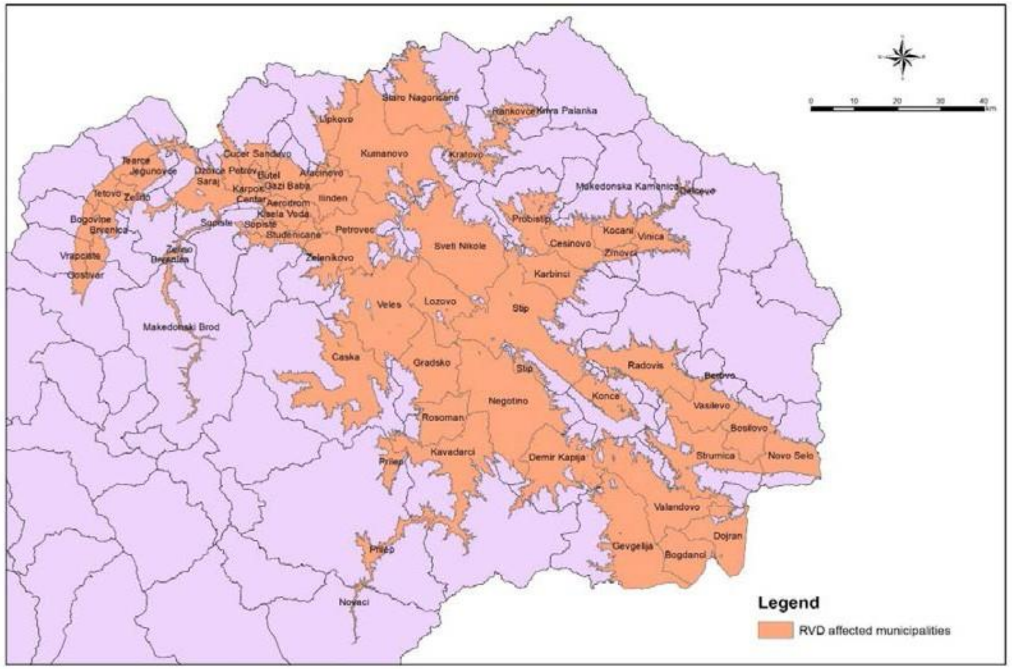
Region Vulnerable to desertification

- ✓According to the UNCCD, desertification cannot exists without a certain level of aridity (between 0.05 and 0.65).
- ✓28% of the country area prone to desertification
- ✓18,4% are near to the threshold of 0.65

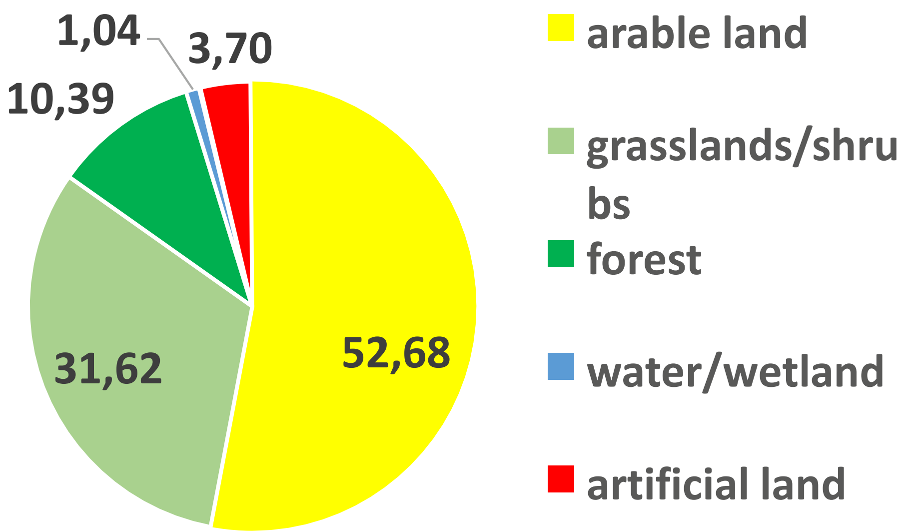


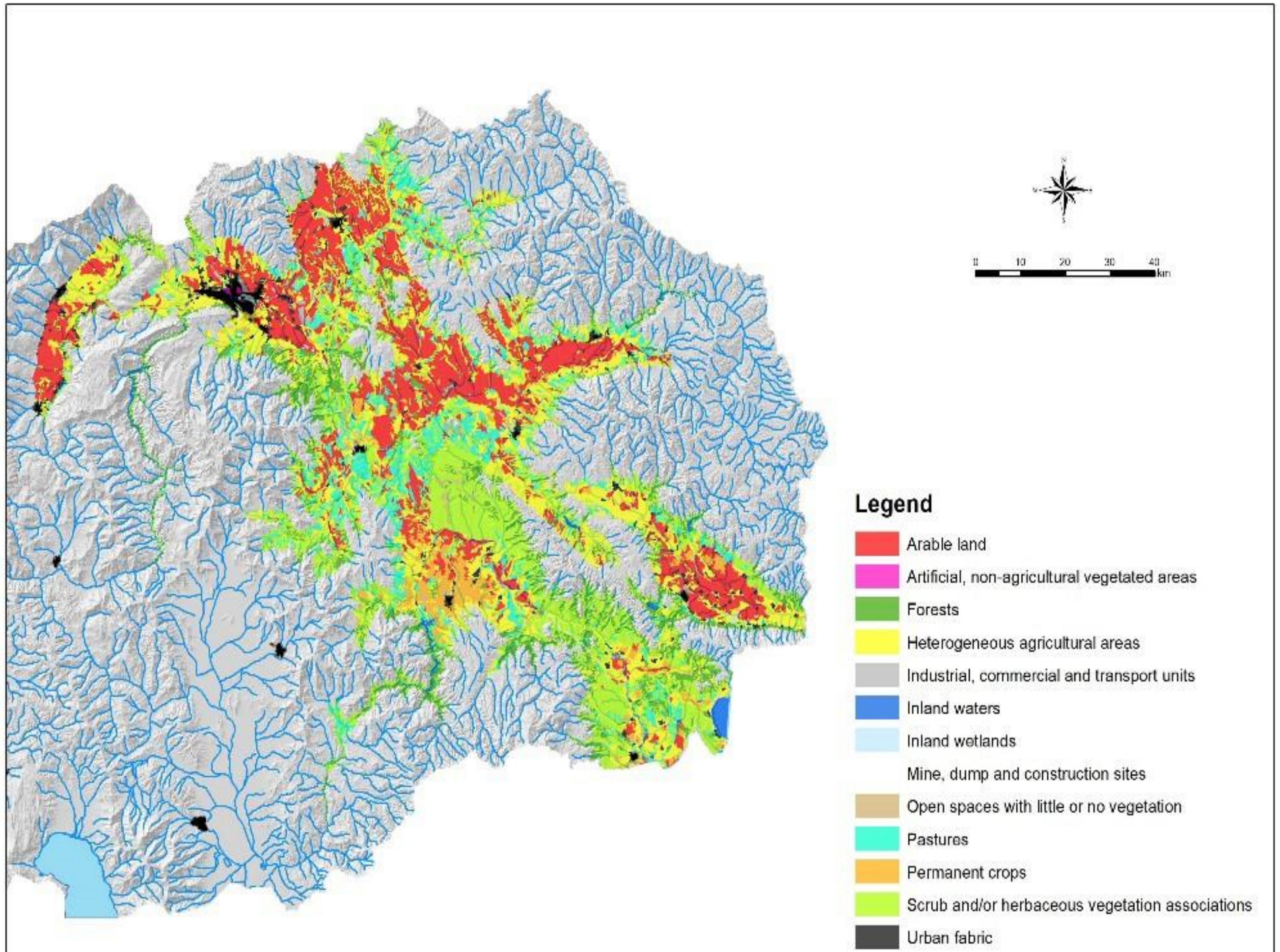
• REGION VULNERABLE to DESERTIFICATION

61 Local municipalities



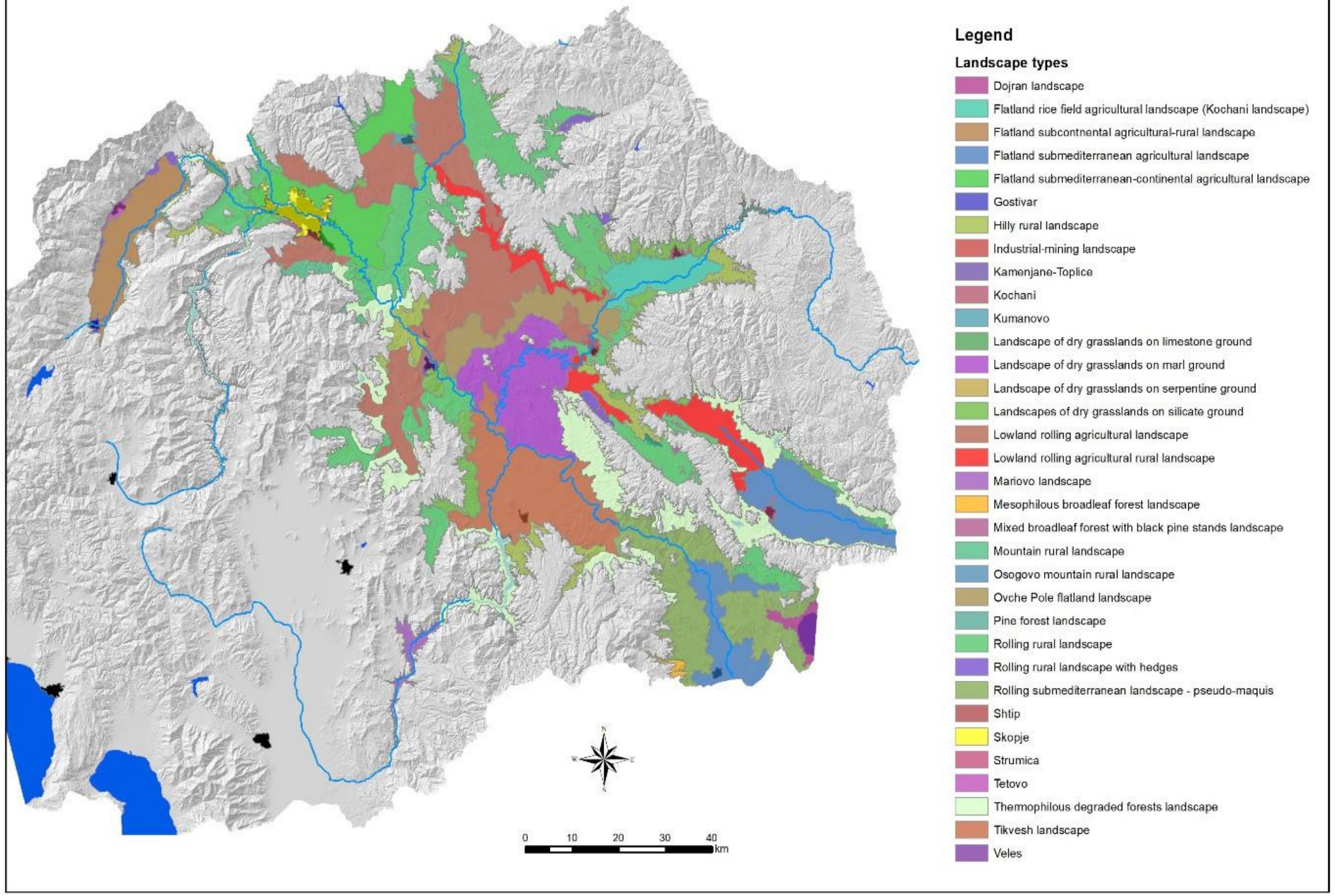
Distribution of RVD per LC classes





Landscape types

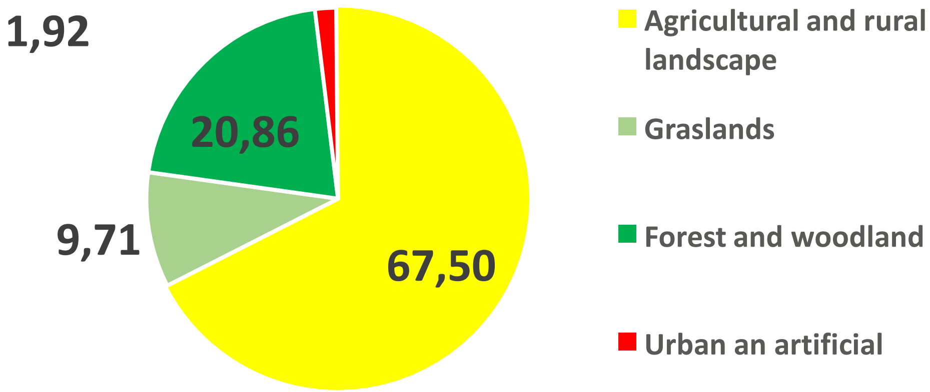
Melovski et al., (2019) delineated landscape types in the RNM and identified in total 41 landscape types, on a higher hierarchical level organized within 8 landscape groups.



Mostly of the area of the RVD is in the following groups:
Agricultural landscape, hilly dry grassland landscape and rural landscape.

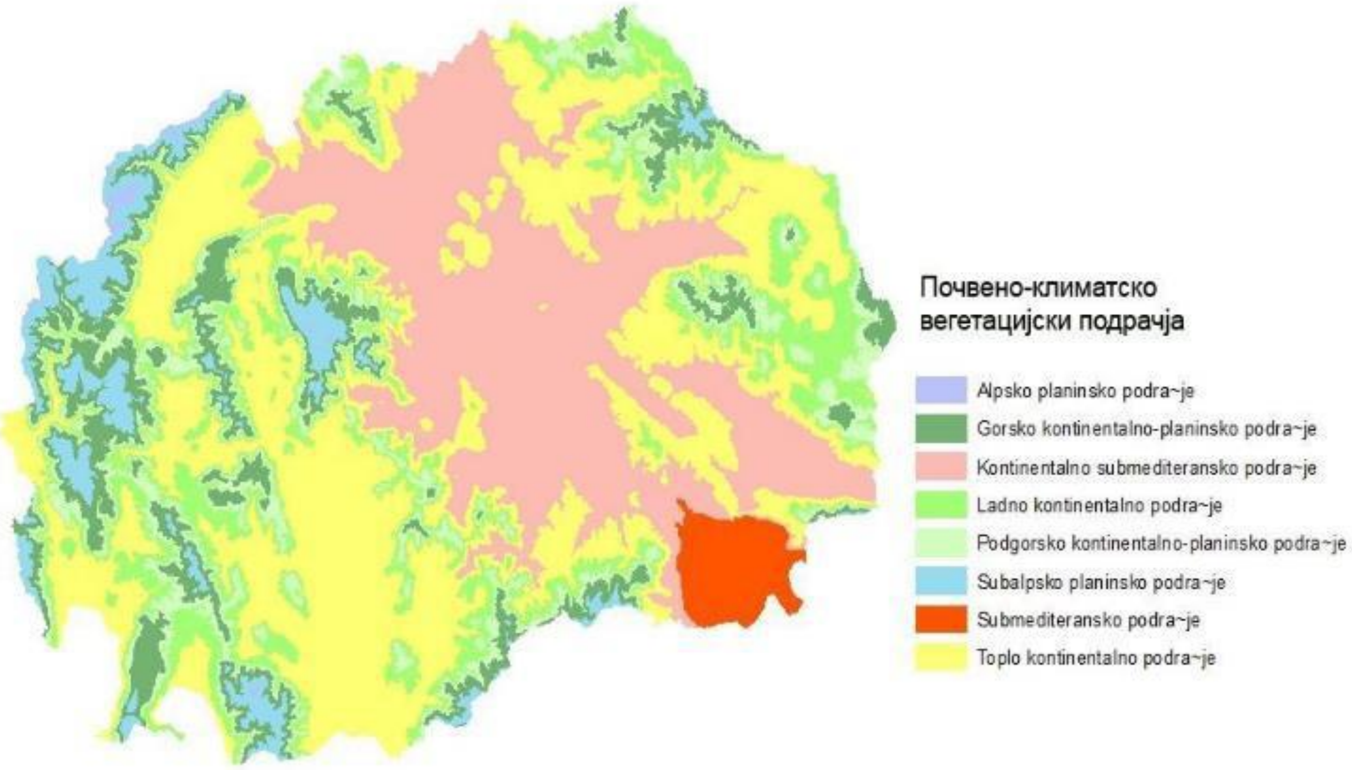
Small parts of the region are with:
urban and industrial-mining landscape, forest landscape and lake landscape.

Distribution of RVD per landscape groups



Soil Climate-vegetation zones in Region Vulnerable to Desertification

- According to the Soil-Climate-Vegetation zoning (Filipovski – Rizovski – Risteski ,1996) region vulnerable to desertification covers 2 regions:
- Region with a sub-Mediterranean climate (50 - 500 m Gevgelija-Valandovo region) (SM); and
- Region with a moderate-continental-sub-Mediterranean climate (to 600 m) (MCSM).



SM region - Dominant plant association is: *Coccifero-Carpinetum orientalis Oberd.emend.Ht*.

MCSM region - Dominant plant association: *Querco-Carpinetum orientalis Rud.apud.Ht*

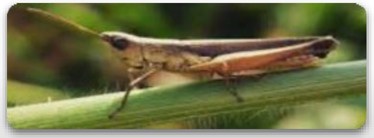
Paliurus aculeatus Lam.
(*Paliurus spina-Christi Mill.*)

Habitats , flora and fauna (NBSAP)

- **Mediterranean semi-deserts** generally are Aegean-Anatolian rocky semi-desserts. They contain species which are central Asian and rarely African i.e. paleotropical elements.

Plants

Carduus hamulosus, Eryngium campestre, Eryngium palmatum, Carthamus lanatus, Rosa spinosissima, Stachys recta, Galium purpureum, Stipa tirsa, Stipa mediterranea, Triticum villosum



Grasshoppers

Calliptamus italicus, Dosciostaurus marrocanus, Oedipoda miniata, Glyphothmetis heldreichii, Asiothmetis limbatus, Paracalopternus caloptenoides, Acrida sp.

Ground beetles

Harpalus metallinus, Carabus graecus morio, Pachycarus cyaneus, Brachinus brevicollis

Arthropods

Galeodes elegans, Latrodectus tredecimguttatus, Mesobuthus gibbosus.

Reptiles

Testudo graeca, Lacerta erhardii, Elalphe quattuorlineata, and probably and viper *Vipera ammodytes*

Birds

Emberiza caesia, Sturnus roseus, Melanocorypha calandra, Burrhinus oedicnemus, Otis tetrax.

Mammals

Vormela peregusna, Microthus guenther

Habitats , flora and fauna (NBSAP)

Sub-Mediterranean Balkan Forests covers Southeast Europe and Asia Minor. Anthropogenic intervention has turned most of this biome into arable land and rocky slopes which are now part of the zonobiome of the Mediterranean semi-deserts. Most characteristic natural habitats in the central part of te country is Eastern Hornbeam and Oriental Hornbeam (*Phyllireo-Carpinetum orientalis*).

Plants

Quercus pubescens, Carpinus orientalis, Ostrya carpinifolia, Corylus colurna, Celtis australis, Crateaegus orientalis, Cotinus coggygria, Syringa vulgaris, Tilia argentea, Juglans regia.

Reptiles

Eurotestudo hermanni, Lacerta trilineata, Ablepharus kitaibelii

Birds

Parus *lugubris, Dendrocopos syriacus, Ficedula semitorquata, Streptopelia decaocto, Accipiter brevipes*

Mammals

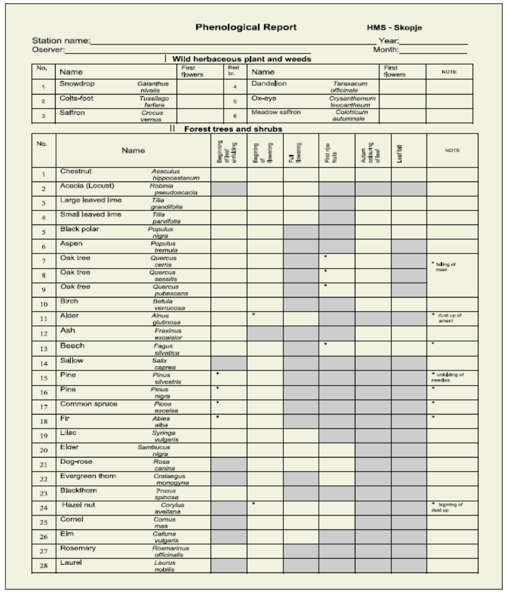
Dryomis nitedula, Apodemus flavicollis, Glis glis, Erinaceus roumanicus

Pseudo-maquis cover area from exit of Vardar river in Demira Kapija gorge up to the border with Greece. This area encompass region of Gevgelija - Valandovo. Kermes Oak (*Quercus Coccifera* L.) is typical represent of association Coccifero-Carpinetum Orientalis *Oberd*. *1948*) *em Ht., 1954*

Phenological data as a key indicator of the effects of climate change on biodiversity

Phenological data is digitized for forest trees and shrubs for the last 20 year of observation from all 24 phenological stations from the monitoring system of North Macedonia. The observed program considers the following phenological phases:

- Beginning of leaf unfolding
- Beginning of flowering BBCH 60
- Full flowering
- First ripe fruits
- Autumn coloring of leaf
- Leaf fall



Phenological Report HMS - Skopje

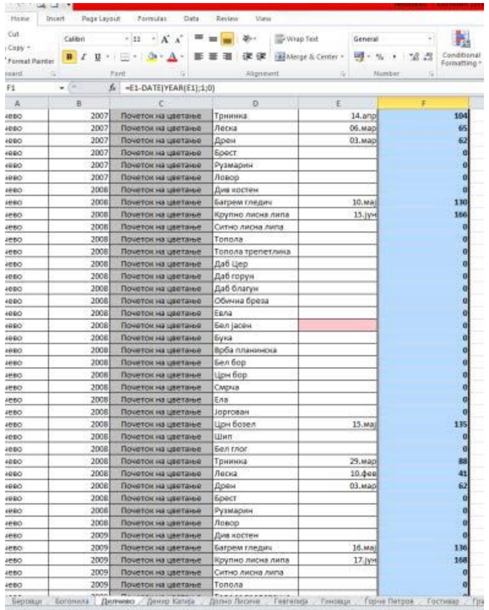
Station name:____ Year:____
Oserver:____ Month:____

I Wild herbaceous plant and weeds

No.	Name		First flowers	Red br.	Name		First flowers	NOTE
1	Snowdrop	*Galanthus nivalis*		4	Dandelion	*Taraxacum officinale*		
2	Colts-foot	*Tussilago farfara*		5	Ox-eye	*Crysanthemum leucantheum*		
3	Saffron	*Crocus vernus*		6	Meadow saffron	*Colchicum autumnale*		

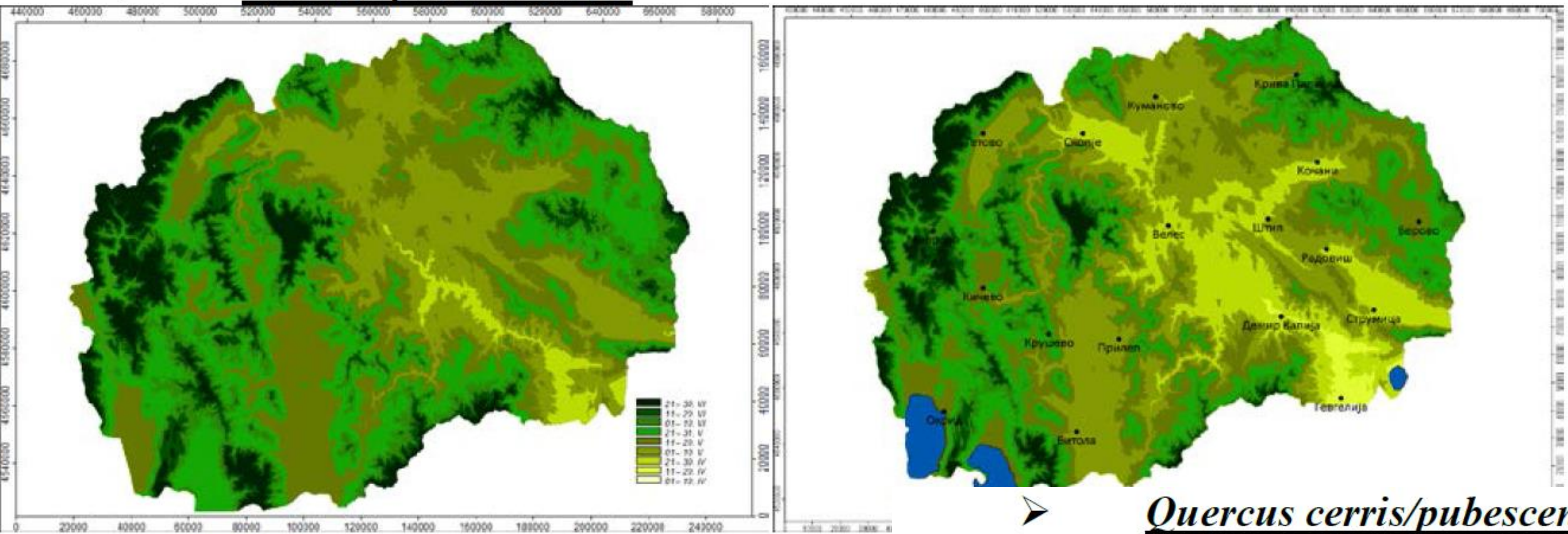
II Forest trees and shrubs

No.	Name		Beginning of leaf unfolding	Begining of flowering	Full flowering	First ripe fruits	Autum colouring of leaf	Leaf fall	NOTE
1	Chestnut	*Aesculus hippocastanum*							
2	Acacia (Locust)	*Robinia pseudoacacia*							
3	Large leaved lime	*Tilia grandifolia*							
4	Small leaved lime	*Tilia parvifolia*							
5	Black polar	*Populus nigra*							
6	Aspen	*Populus tremula*							
7	Oak tree	*Quercus cerris*				*			* falling of mast
8	Oak tree	*Quercus sessilis*				*			
9	Oak tree	*Quercus pubescens*				*			
10	Birch	*Betula verrucosa*							
11	Alder	*Alnus glutinosa*		*					* dust up of ament
12	Ash	*Fraxinus excalsior*							
13	Beech	*Fagus silvatica*				*			*
14	Sallow	*Salix caprea*							
15	Pine	*Pinus silvestris*	*						* unfolding of needles
16	Pine	*Pinus nigra*	*						*
17	Common spruce	*Picea excelsa*	*						*
18	Fir	*Abies alba*	*						*
19	Lilac	*Syringa vulgaris*							
20	Elder	*Sambucus nigra*							
21	Dog-rose	*Rosa canina*							
22	Evergreen thorn	*Crataegus monogyna*							
23	Blackthorn	*Prunus spinosa*							
24	Hazel nut	*Corylus avellana*		*					* bigining of dust up
25	Cornel	*Cornus mas*							
26	Elm	*Calluna vulgaris*							
27	Rosemary	*Rosmarinus officinalis*							
28	Laurel	*Laurus nobilis*							

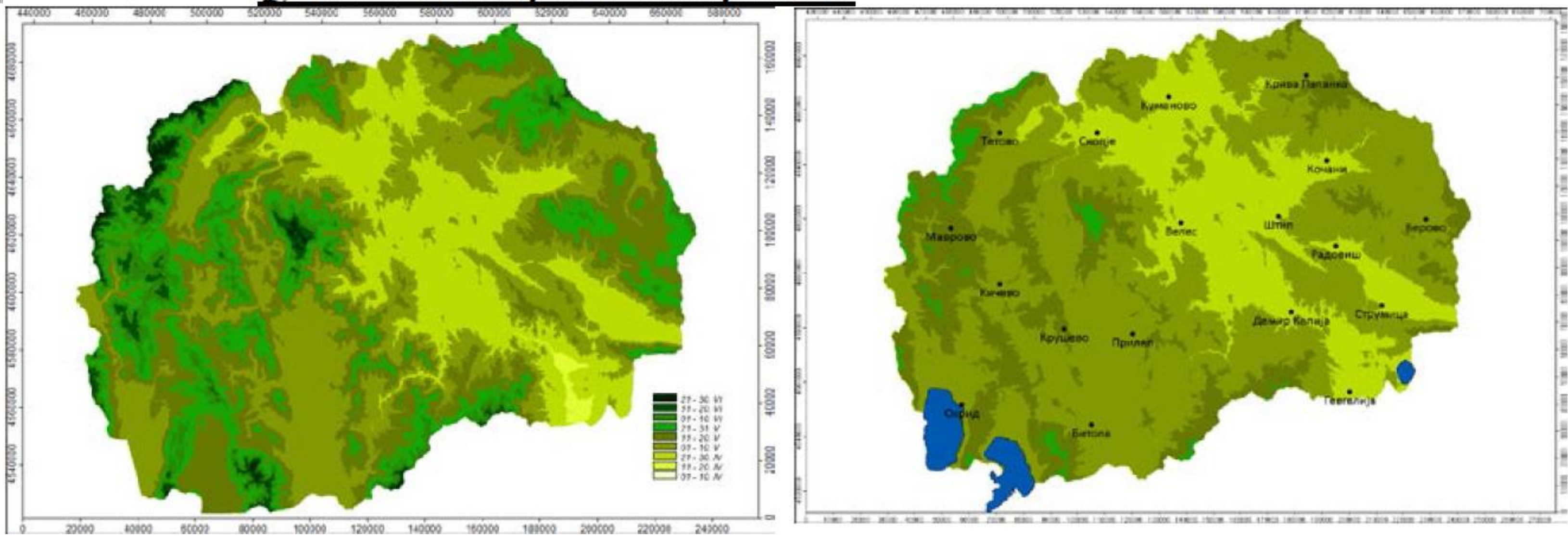


- The selected species are Horse-chestnut (*Aesculus hippocastanum*), Locust (*Robinia pseudoacacia*) and Oak tree (*Quercus sp.*). For the phenological phase "beginning of flowering BBCH 60" we have prepared spatial maps in GIS environment for historical averaged period 1961-1990 and for 2009 -2018 period

➢ ***Robinia pseudoacacia***



➢ ***Quercus cerris/pubescens/petraea***



Comparative analyzes of this phenological phase for the past thirty-year period versus more recent twenty-year period show changes in the average date of the beginning of flowering. It is noted that the average time of onset of flowering begins earlier, especially in the central part of N. Macedonia. This change is mostly evident in *Robinia pseudoacacia*.

Recommendations

- Climatological aspects
-
- Widening the network of climatological stations, especially at altitudes above 1000 m asl.
- Development of 30-minutes rainfall dataset as a necessity for modeling rainfall in RRUSLE and EPM. There are some outdated datasets and they should be updated.
- Precipitation data for high mountain region is not certain and complete. Should be developed data for higher gauge stations to be included in modelling later
- Data for intensive precipitations is limited only on several meteorological stations
- Strengthening and providing continuity of meteorological measurements and observations at current meteorological measuring stations
- Additional measurement in regions with higher risk and inclusion of Satellite (remote sensing) monitoring
- Establishment of coordination mechanisms for use of meteorological data from other national sources
-

• Erosion

-

- Advance improve of EPM for the regions with alpine configuration like in the western part of the country . It is very important for engineering projects. Possible solutions manual adding specific source iof sediments, introducing of category "extreme erosion" for specific sources of saedeimnets……

- According to the Law on Water, each municipality and water economy unit are obliged to adopt erosive areas and areas prone to erosion (actual and potential risk areas)based on a technical project. At the moment they have no capacities to do this.
- Current map is only Erosion hazard map, but to become Erosion Risk map should be added the elements of risk.

- Monitoring of siltation of reservoirs should be established as continual practice every 5 years in order to monitor the siltation regime and it can be used for validation of the results of the modelling

Desertification

- Evaluation and Selection of Indicators for Land Degradation and Desertification Monitoring
- Socio-economic research in region vulnerable to desertification (agriculture, forestry, water economy, economic status of citizens including, poverty, etc.).
- Estimation of the risk for appearance of desertification, based on regional climate projection up to 2100 (based on different emission scenarios- RCP). This includes verification and adoption of a single aridity index, calculation and comparison using historical data from the beginning of measurement up to 1981.
- Desertification risk assessment (including socieo-economic parameters etc.) according to latest approaches in EU
- Setting a scene for preparation of risk management plan: as a first phase selection of several highest vulnerable sites, representatives of biodiversity species with regular monitoring and elaboration of periodical (annual, biannual or different period) assessment of the state of desertification impact.

BFSD BALKAN FOUNDATION FOR SUSTAINABLE DEVELOPMENT

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Република Северна Македонија
Министерство за животна средина и просторно планирање

Republika e Maqedonisë së Veriut
Ministria e Mjedisit Jetësor dhe Planifikimit Hapësinor

Last Slide

It's not over...