Project Report

"Ecological Data Gap Analysis and Ecological Sensitivity Map Development for the Bregalnica River Watershed"

Dekons-Ema and Macedonian Ecological Society

Book 5

Ecological Sensitivity Map of Bregalnica watershed

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CONTENTS

1 Introduction 5

2 Methodology.. 8

2.1 Valorization of the criteria and indicators used to produce the sensitivity map 9

2.1.1 Criterion: Structural aspects of the habitat patches... 9

2.1.1.1 Indicator 1.1: Fractal Coefficient of Perimeter (FPC) of the habitat patches 9

2.1.1.2 Indicator 1.2: Habitat compactness - Circularity Ratio of the Area (CRA) of the habitat patches 10

2.1.1.3 Indicator 1.3: Average slope 10

2.1.2 Criterion 2: Compositional aspects of the habitats [presence of important plant species (Indicator 2.1), important animal species (Indicator 2.2) and important habitats (Indicator 2.3)] 11

2.1.3 Criterion 3: Abiotic risks 18

2.1.3.1 Indicator 3.1: Landslide risk Indicator 18

2.1.3.2 Indicator 3.2: Fire risk Indicator - Fire potential index (FPI) 19

2.1.3.3 Indicator 3.3: Habitat aspect (orientation) compared to the main wind direction Indicator 21

2.1.4 Criterion 4: Habitat patch isolation (connectivity, corridors and core patch importance).. 22

2.1.4.1 Indicator 4.1: Presence of corridors that connect the core patches for forest species (4.4 – steppe species, 4.7 – high mountain species). 22

2.1.4.2 Indicator 4.2: Presence of habitat patches, categorized according to their influence on core patch connectivity in the study area, from the perspective of the forest species (4.5 – steppe and 4.8 high-mountain species).. 26

2.1.4.3 Indicator 4.3: Presence of core patches for forest species (4.6 – steppe and 4.9 – high-mountain species), categorized according to their overall importance for the connectivity of the whole study area 28

2.2 Calculation of the Ecological Sensitivity map values 31

3 Analyzes of Ecological Sensitivity Map and Recommendations 33
3.1 Proclamation of Protected Areas 34
3.2 Conservation Action Plans 36
3.3 Species reintroduction 36
3.4 Biocorridors management 36
3.5 Biosphere Reserves 37

4 References 38

1 Introduction

The Republic of Macedonia is still using traditional approach to nature protection. The main conservation tool to be used is establishment of protected areas, although the national network of protected areas is far from completion. The Law on Nature Protection prescribes other proactive management tools for the biodiversity conservation but these were only used in separate projects and they can not be considered as country national policy. Other sectoral policies such as laws regulating forestry, hunting, fishing, etc. are also important for nature conservation in Macedonia but they focus more on exploitation of natural resources rather than its protection.

During the past few decades, the low effectiveness of the current nature conservation policies to contrast the growing environmental pressures and to protect the ecological processes ensuring the biodiversity maintenance has clearly emerged in Europe (Pecci 2010). In the recent past the scientific literature has mainly dealt with biodiversity preserve design but proactive conservation planning is becoming increasingly important due to the growing threats to biodiversity and the limited financial resources.

Many studies have underlined that the preservation of species populations, communities and ecosystems cannot be limited to the establishment of protected areas and biosphere reserves, especially if isolated or small, but it is necessary to take into account the ecological-environmental processes concerning broader scales than those involved in the single protected areas (Pecci 2010). The biodiversity value as natural heritage of a country includes not only the areas officially protected but also all the diffuse naturalistic traits of the landscape which, even if external to the protected areas, play a strategic role in maintaining the same protected areas. Particularly, what emerged was the awareness that the persistency of the biodiversity is strongly contrasted by the growing fragmentation of natural and semi-natural environments, and that biodiversity can be preserved only through adequate land-use planning extended to the whole landscape (Pecci 2010). From this point of view, the maintenance of a physical-territorial and of an ecological/functional continuity among natural and semi-natural environments has been suggested as an effective strategy in order to mitigate the effects of fragmentation on populations and communities (Pecci 2010).

The Republic of Macedonia has prepared its national ecological network – MAK-NEN. The concept of ecological network assumes a system of sustainably managed areas which are cores of the populations of important species, mutually connected through corridors which enable the organisms to migrate easily from one to another core area, thus providing genetic connection and vitality of their populations. Establishment of a coherent ecological network of core areas, corridors, buffer zones and restoration area, as a new model of biological diversity conservation has been considered as one of the most efficient measures for its conservation providing at the same time the possibility for sustainable use of nature. In addition to this, ecological network contributes to the mitigation of the climate change effects. Spatial planning, as a tool for establishment of balance between social, economic and environmental needs in land use, plays the main role in the implementation of the ecological networks. Integration of MAK-NEN in the Spatial Plan of the Republic of Macedonia, as basic strategic document in land use planning, is a great challenge. Unfortunately, MAK-NEN has still not being adopted by the Government and does not represent a legal obligation. However, it provides a vision (map of opportunities), a concept for environment preservation and it should be incorporated in all segments of the Macedonian society. Its implementation requires the will of different institutions and organizations and its use in the development of various analyses, studies, application of environmental impact assessment studies for certain projects, etc. (Brajanoska et al. 2011).

The pursuit of environmental continuity has given rise to the development of a specific area of the territorial planning, the ecological networks design, in a perspective of general rethinking of the tools for land control, management and protection. The topic of ecological networks is now established as focal in environmental politics, starting programmes and initiatives corresponding to alogic of integration (i.e. of network) among individual actions on the environment. The knowledge concerning the ecological networks theme has been partly acquired at a planning level, and not only at a normative one.This knowledge is included in International conventions (European Landscape Convention, 2000), in Council Directives of the EEC (Acquis of the European Union), in pan-European strategies and in national guidelines (Pecci 2010).

The Council Directive on conservation of wild birds 2009/147/EC ex. 79/409/EEC (Birds Directive, 1979), concerning the designation of Special Protection Areas (SPAs), and the Council Directive on the conservation of natural habitats and of wild fauna and flora 92/43/EEC (Habitats Directive, 1992), aimed to designate Special Areas of Conservation (SACs), have achieved a great importance for nature conservation in Europe. These Directives represent the legal framework for establishment of "Natura 2000"; it is the most important project concerning the nature conservation and biodiversity monitoring and involving the whole European Union (EU) territory. Natura 2000 network is also important for Macedonia as accession country. The basic aim of this Network is the natural and seminatural habitats and wildlife conservation to preserve the biodiversity through the detection and effective management of the sites provided for "Habitats Directive" and "Birds Directive" (Pecci 2010).

Furthermore Natura 2000 enables establishment of a system of strictly connected areas from a functional point of view. Natura 2000 network assign relevance not only to the highly natural areas but also to the contiguous territories essential to relate areas spatially far but near considering their ecological functionality. Moreover the need is not to manage and protect a set of disjoined areas, but to provide resources and knowledge, to study management models of Natura 2000 sites and share experience between countries that has already established it. This aspect will allow to start a "relations network" on the territory, permitting a "dialogue" among the areas, establishing the conditions for ecological connections (Pecci 2010). This allows successful cooperation and brings positive changes and improvement of the managing system of protected areas in the country. Natura 2000 is an example of an EU-wide ecological network-building process. Through involvement of all relevant stakeholders – landowners, land users, local, national and European authorities – across all sectors, it aims at ensuring biodiversity conservation beyond national boundaries (Brajanoska et al. 2009).

The methodology used for the elaboration of Ecological Sensitivity Map enabled the individuation of the so called "hotspots" (i.e. ecological critical points/objects/areas or their clusters). The general environmental goal of this methodology is to individuate and propose some statistical tools useful for the conservation of the biodiversity values. This aim includes not only the areas officially protected or proposed for protection, but also all the diffuse naturalistic traits of the landscape which, even if external to the protected areas, play a strategic role in maintaining the same protected areas. From this point of view it is suggested the necessity to overcome the peculiar "limits" of the ecological basic research, so that the obtained results can be easier understandable and usable also by the administrative and political decision-makers. Indeed the decision makers are more and more often involved in deliberating actions that affect critical areas without having appropriate cognitive support (Pecci 2010).

Since any form of environmental policy in practice finds expression in funds to spend in local administrative partitions involved in ecologically critical situations, there is the primary necessity to find methodologies to identify environmental critical points in order to guide public stakeholders in allocating funds only where it is truly necessary. It is also necessary to integrate ecological-naturalistic information in the human context in order to ameliorate the environmental evaluations and to provide guidelines for conservation action and planning. Planning for conservation is a process that uses scientific data, but that ultimately depends on the expression of human values (Pecci 2010).

Importance of the landscapes for biodiversity is presently recognized the worldwide in biodiversity conservation efforts. The joined statement of the world's leading nature conservation organizations in 1999 is an example (Melovski et al. 2015): "It is crucial to implement integrated conservation and development plans and programs on a larger scale than those that have been attempted so far. Presently nature conservation focus is broadening to encompass landscape, working closely with the key stakeholders. This will help to address more effectively the broader social, economic, and policy factors that are critical to sustainable livelihoods and ecosystems".

The Ecological Sensitivity Map of Bregalnica watershed clearly shows the hotspots and other areas important for management of natural and seminatural ecosystems. Information shown on the map overlaps with the proposals for protected areas to a certain degree. One should have in mind that the design of the protected areas network relies on the data on natural and biodiversity values, but also includes subjectively-assessed values, especially values such as aesthetic characteristics and natural rarities. The opinion of local stakeholders and general attitude of the society also play an important role in designing of the protected areas system. The Ecological Sensitivity Map overcomes these lacks of traditional protected areas systems and as already stated it enables protection outside of protected areas. However, the Macedonian legislation still favours the creation of traditional protected areas; but this concept will have to change in time because Ecological Sensitivity Map provides the most contemporary and probably the most effective tools for nature and biodiversity conservation.

2 Methodology

Habitat ecological sensitivity is defined as habitat proneness to environmental change involving a combination of intrinsic and extrinsic factors (Nilsson and Grelsson, 1995; Ratcliffe, 1977). In order to effectively develop this multidimensional concept a set of 18 indicators has been used sorted in 4 groups (Таб. 1). All these indicators are correlated with the risk of a habitat of being damaged or losing its ecological identity/integrity. The methodology used in this work is an adaptation of the already existing methodology that have been used for biodiversity hot-spots identification in several regions in Italy, in order to prioritize the regions where conservation measures need to be undertaken (Rossi, 2005).

Table 1. Criteria and corresponding indicators for the evaluation of the ecological sensitivity of the Bregalnica river watershed and the East Planning Region of the Republic of Macedonia.

CRITERIA	INDICATORS
1. STRUCTURAL ASPECTS	1.1 Fractal Coefficient of perimeter (FCP)
	1.2 Circularity Ratio of area (CRA)
	1.3 Average slope
2. COMPOSITIONAL ASPECTS	2.1 Presence of important animal species
	2.2 Presence of important plant species
	2.3 Presence of important habitats
3. ABIOTIC RISKS	3.1 Landslide Index
	3.2 Fire Potential Index (FPI)
	3.3 Orientation compared to the main wind direction
4. ISOLATION	4.1 Presence and importance of corridors for forest species
	4.2 Connectivity of habitat patches for forest species
	4.3 Presence and importance of core areas for forest species
	4.1 Presence and importance of corridors for steppe species
	4.2 Connectivity of habitat patches for steppe species
	4.3 Presence and importance of core areas for steppe species
	4.1 Presence and importance of corridors for high-mountain pasture species
	4.2 Connectivity of habitat patches for high-mountain pasture species
	4.3 Presence and importance of core areas for high-mountain pasture species

2.1 Valorization of the criteria and indicators used to produce the sensitivity map

2.1.1 Criterion: Structural aspects of the habitat patches

2.1.1.1 Indicator 1.1: Fractal Coefficient of Perimeter (FPC) of the habitat patches

FPC reflects the level of convolution of each habitat patch. Regarding the perimeter convolution, literature suggests that ecosystems receiving several kinds of inputs from many directions are the ones more likely to be at risk of losing their identity (Ratcliffe, 1977). All other things being equal, the more irregular the perimeter of the habitat patch, the greater it's opening to the dynamic external forces which press on its identity and/or its integrity (Pecci, 2010).

The coefficient can be estimated with the equation:

FCP = [2 * ln (Perimeter) / ln (Area)], with possible values in the range [1 - 2].

The value of this indicator in the map of sensitivity (Fig. 1) was calculated for 1km^2 cells of a UTM grid, as a sum of products of the value "FCP-1" of the habitat patches that inhabit a cell and their respective areas (in km2) inside the cell.

Lowering the original FCP values by "1" is done for normalization of the Indicator values in the range [0 - 1].

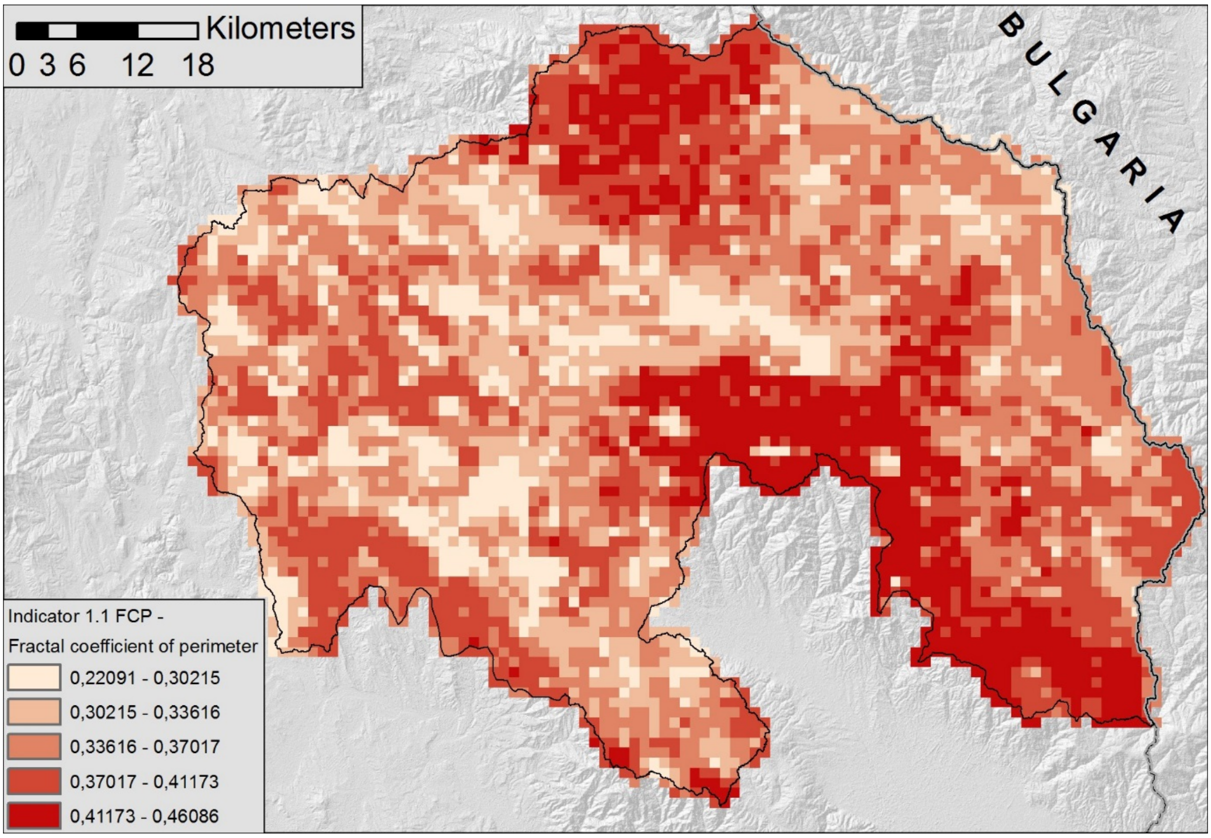

Figure 1. Map of values for the Indicator 1.1 – Fractal Coefficient of Perimeter of the habitat patches

2.1.1.2 Indicator 1.2: Habitat compactness - Circularity Ratio of the Area (CRA) of the habitat patches

Like perimeter convolution, shape compactness of a habitat is a structural characteristic which has ecological involvements (Forman, 1995) and reflects the level of exposure of patches to extrinsic factors. Indeed, compact shapes are functional to maintaining habitat resources because they minimize perimeter exposure and contact with surrounding environment (Pecci, 2010).

High values are calculated for the patches whose form is close to circular, which is expected if we take into consideration that the coefficient is calculated as a relation between area of the patch and the area of its minimal circular form:

CRA = AREAPATCH / AREACIRCLE.

All other things being equal, a value close to 1 implies great power to preserve the internal abiotic and biotic resources. A value close to "0" describes the opposite situation.

The value of this indicator in the map of sensitivity (Fig. 2) was calculated for 1km^2 cells of a UTM grid, as a sum of products of the values of "1 - CRA" of the habitat patches that inhabit a cell and their respective areas (in km2) inside the cell.

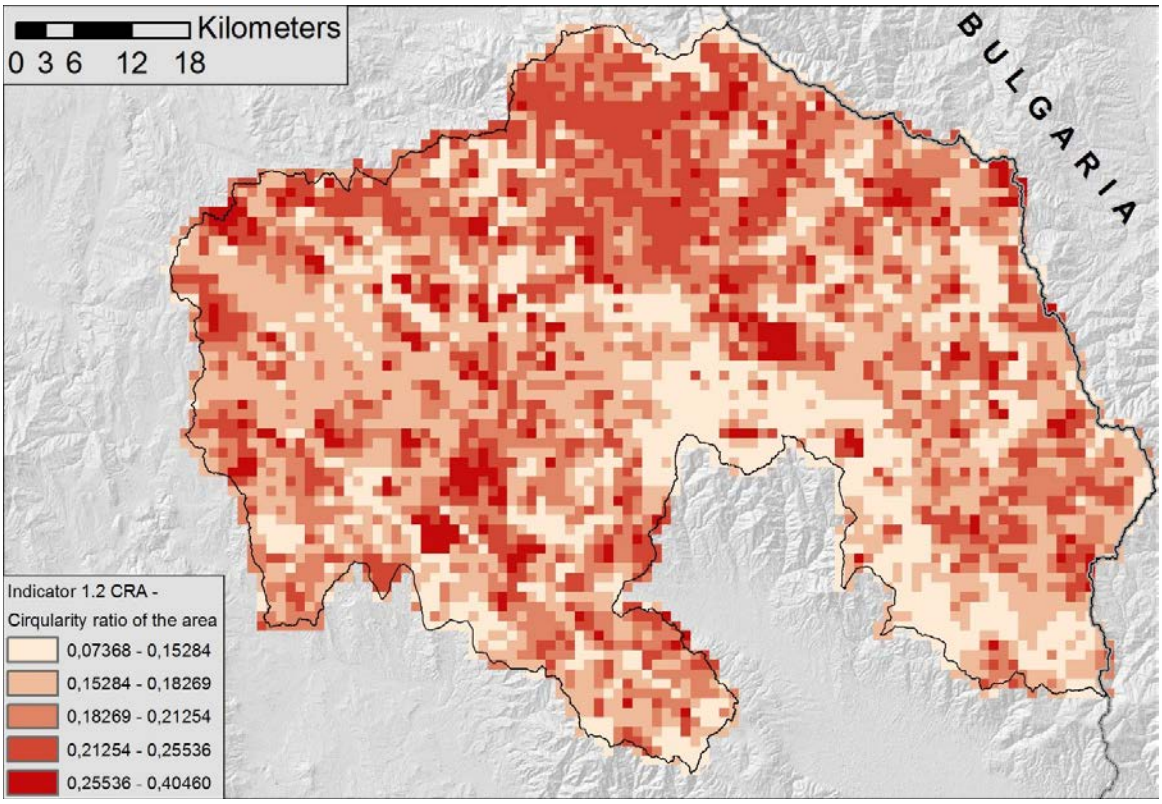

Figure 2. Map of values for the Indicator 1.2 – Compactness of the habitat patches.

2.1.1.3 Indicator 1.3: Average slope

Terrain slope affects soil quality and depth, implying a change in habitat integrity.

We have used data from the Digital Elevation Model (DEM) (ASTER GDEM, 2011), with original resolution of 1 arc second (~ 30m x 24m in the study area), where the altitude values are represented in meters.

The geographic coordinate projection of the DEM was transformed from WGS84 into UTM 34T coordinates (metric).

The slope model was generated (24m x 24m pixel resolution, slope values in degrees) with "Spatial Analyst" tools for ArcGIS 10.2 (ESRI, 2013), using the re-projected DEM.

The value of this indicator in the map of sensitivity (Fig. 3) was calculated for 1km^2 cells of a UTM grid, as the mean value of all the slope values inside a cell, divided with the value "90" (normalization of the Indicator values in the range [0 - 1]).

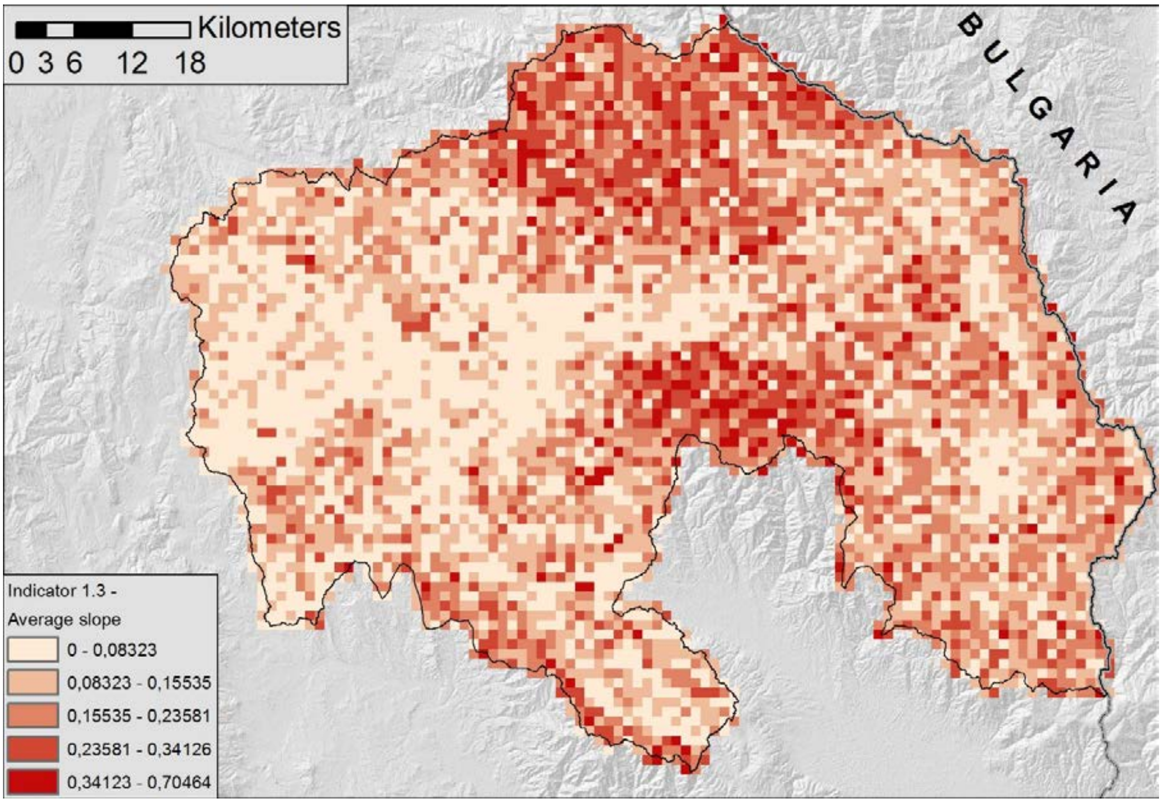

Figure 3. Map of values for the Indicator 1.3 – Average slope

2.1.2 Criterion 2: Compositional aspects of the habitats [presence of important plant species (Indicator 2.1), important animal species (Indicator 2.2) and important habitats (Indicator 2.3)]

All three indicators of this criterion were analyzed jointly, and as a result of this, a unique value was calculated – indicator for the importance of the biodiversity (Fig. 4), of values with logarithm function performed before their normalization in the scope [0 - 1]. Due to grouping of the values of the 3 indicators into one, the value of the combined indicator is multiplied by factor 3 in the final calculation of the values of Ecological Sensitivity map.

For defining the indicator for importance of biodiversity, the data on species and habitats were applied on UTM grid with resolution of 1 km2, and presented as presence and absence of the species and habitats in that area. Visually, this will lead to a map with reduced resolution, but it's the only way to present a lot of data of different resolution for relatively big surface of a map.

During second step, each of the species and habitats were evaluated according to national and international criteria: Red lists, EU directives, conventions, legislation in the Republic of Macedonia, endemism, rarity, economical value and importance of the region for its conservation.

The principle of grading each species and habitat is presented in following text:

- **Global IUCN Red list** – the latest assessment form 19th November 2015 was used (IUCN, 2015). The Extinct species were not graded, because we cannot be always sure whether the area of their former presence have the conditions for their survival nowadays. The presented scale of grading (Table 2) probably underestimates the values of the grid cells, especially due to high number of non-evaluated species (NE – Not Evaluated) or data deficient species (DD – Data Deficient) (Bland et al., 2014).

Table 2. Grading the presence of species according to the their status in the Global IUCN Red list

Category	Value
CR - Critically endangered	4
EN - Endangered	3
VU - Vulnerable	2
NT - Near Threatened	1
EX - Extinct	0
EW - Extinct in the wild	0
LC - Least Concern	0
DD - Data Deficient	0
NE – Not Evaluated	0

- **European Red lists** – produced only for some taxonomical or ecological groups, of which important for Macedonia are: amphibians (Temple and Cox, 2009), reptiles (Cox and Temple, 2009), birds (BirdLife International, 2015), mammals (Temple and Terry, 2007), butterflies (van Swaay et al., 2010), bees и beetles (Nieto et al., 2014), saproxylic beetles (Nieto and Alexander, 2010), dragonflies (Kalkman et al., 2010) and freshwater and terrestrial mollusks (Cuttelod et al., 2011). The category Regionally Extinct (RE – Regionally Extinct) was also added and graded without score, due to the same reasons as the category Extinct. The grading is presented in Table 3.

Table 3. Grading the presence of species according to their status in European Red lists

Category	Value
CR - Critically endangered	4
EN - Endangered	3
VU - Vulnerable	2
NT - Near Threatened	1
EX - Extinct	0
RE - Regionally extinct	0
EW - Extinct in the wild	0
LC - Least Concern	0
DD - Data Deficient	0
NE – Not Evaluated	0

- **Birds Directive** (The European Parliament and The Council of the European Union, 2009) – only the species included in Annex I of the Directive (species requiring designation of Special Protection Areas) are graded with score. Having in mind the inclusion of the Macedonian species in different annexes, the grading is presenting in Table 4:

Table 4. Grading the presence of species according to the inclusion in the Annexes of the Birds Directive

Annex	Value
Annex I	1
Annexes I; II/A	1
Annexes I; II/B	1
Annexes I; II/B; III/B	1
Annex II/A	0
Annexes II/A; III/A	0
Annexes II/A; III/B	0
Annex II/B	0
Annexes II/B; III/B	0
Not included	0
Inapplicable	0

- **EU Species and Habitats Directive** (The Council of the European Union, 1992) **–** the habitats were graded separately from the species. The inclusion of certain habitat in Annex I, had score 2 for the grid cell, and if that habitat in the Annex was selected as priority for protection, the grid cell got score 3. The presence of species included both in Annex I (species requiring protected areas) and Annex IV (protected species) graded the grid cell with score 3. The other principles of grading are shown in Table 5.

Table 5. Grading the presence of species according to the inclusion in the Annexes of the EU Species and Habitats Directive

Annex	Value
Priority habitat	3
Annex I	2
Annexes II; IV	3
Annex II	2
Annex IV	1
Annexes III; IV	1
Not included	0
Annex V	0
Inapplicable	0

- The grading according to the **Convention on the Conservation of European Wildlife and Natural Habitats** (The Council of the European Union, 1979) is presented in Table 6, where the plant species are in Appendix II and the animal species in Appendices II and III.

Table 6. Grading the presence of species according to inclusion in the Appendices of the Convention on the Conservation of European Wildlife and Natural Habitats

Appendix	Value
Appendix I	2
Appendix II	2
Appendix III	1
Not included	0
Inapplicable	0

- According to the inclusion of the species in **Resolution No. 4 listing endangered natural habitats requiring specific conservation** (Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats, 1996) and **Resolution No. 6** listing the species requiring specific habitat conservation measures (Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats, 1998), the grading followed same principle as in EU Habitat Directive – the priority habitats got highest score (2), while the other habitats and species where graded with 1 or 0 according to their inclusion or not in the resolutions (Table 7). The species and the habitats included in these two resolutions are generally known as Emerald species.

Table 7. Grading the presence of species according to inclusion in the Resolution 4 and 6 of the Standing Committee of the Convention on the Conservation of European Wildlife and Natural Habitats

Inclusion	Value
Priority habitat	2
Included	1
Not included	0
Inapplicable	0

- The Convention for Conservation of Migratory Species (UNEP/CMS Secretariat, 1979), for Macedonia is only relevant or birds and bats; inclusion of species in Appendix I gave score 2, and inclusion in Appendix II – score 1(Table 8).

Table 8. Grading the presence of species according to inclusion in the Appendices of the Convention for Conservation of Migratory Species

Appendix	Value
Appendix I; II	2
Appendix II	1
Not included	0
Inapplicable	0

- According to inclusion of the species in the **Lists for designation of strictly protected and protected species** (Official Gazette of RM 39/2011) in accordance to the Law on Nature Protection of RM (Official Gazette of RM 67/2004; 14/2006; 84/2007; 35/2010; 47/2011; 148/2011; 59/2012; 13/2013 и 163/2013), the highest score was given to the strictly protected species (Table 9)

Table 9. Grading the presence of species according to the protection by the national legislation

Law on Nature	Value
Strictly protected	2
Protected	1
Unprotected	0
Inapplicable	0

- According to the provisions of the Law on Hunting (Official Gazette of RM 26/09, 82/09, 136/11, 1/12, 69/13, 164/13 и 187/13, relevant only for mammals and birds), the species with permanent hunting ban got highest score (Table 10):

Table 10. Grading the presence of species according to their status of game species

Protection of game species	Value
Permanent ban	2
Seasonal ban	1
Without protection	0
Non game species	0
Inapplicable	0

- For the other species, it was consider if they have **some direct economic value** for the local population or the industry (edible mushrooms, forest fruits, medical plants, trees or forest habitats) (Table 11)

Table 11. Grading the presence of species according to their relative economic value

Economic value	Value
(mainly) yes	1
(mainly) no	0

- In regards to **endemism**, 3 categories were defined: (Table 12) – local endemics (distributed only at micro locations; with highest value), sub-endemics and Balkan endemics. The principle of inclusion of the taxon was different in different groups – some authors considered only local endemics recognized as species, others considered also subspecies that are endemic to Balkan Peninsula. The habitats were graded as well, if they are considered to be distributed only on Balkan Peninsula, with score 1.

Table 12. Grading the presence of species according to endemism

Endemism	Value
local	3
Sub-endemics	2
Balkan endemics	1
Not endemic	0

- When defining the **national rarity**, the experts were also flexible whether they will grade according to the number of localities where the species or the habitats are present in the Republic of Macedonia, or according to the population size. The species and the habitats were considered as very rare, rare or common (Table 13):

Table 13. Grading the presence of species and habitats according to national distribution of population numbers

Presence	Value
Very rare species and habitats	2
Rare species and habitats	1
Common species and habitats	0

- Finally, in case when the Bregalnica Region has **special importance** for conservation of certain species in Macedonia, the grid cell where this species or habitat is present, got additional score 1. (Table 14).

Table 14. Grading the presence of species and habitats according to importance of Bregalnica Region for their conservation in Macedonia

Regional importance	Value
Region is very important for the species on national level	1
Region is less important for the species on national level	0

By using database with data on distribution of the species and habitats, as well as the principle for defining the grading value for each of them, we made a simple algorithm which calculates sum of grading values for each grid cell separately, at the same time **eliminating the double registrations of the species and habitats.**

This approach tends to highly grade the more explored regions. There was no mode to improve the methodology, as there was impossibility to investigate all groups equally across the region, and thus, the relatively small amount of data for species presence and absence, which prevented modeling of their distribution. On the other hand, the investigations were focused in regions or at localities for which there was a known or presumed presence of important species, and from this aspect, the output was conservative estimation of the values of the areas, which is emphasizing the more important regions on a map, while overestimating the less important ones.

Considering size of the space, as well as the relatively short time period for field research, there were very few or no data for the biodiversity in most of the grid cells. Thus, we accepted the principle that each empty grid cell gets a value which is half of the value of the highly graded bordering grid cell. At same time, every grid cell having values twice less than the value of the highly graded bordering grid cell, its value was increased to a half of the value of the highly graded bordering grid cell. This principle was based on the probability that species found at certain locality may be found in the close vicinity of this locality (Elith and Leathwick, 2009), but it is **conservative in regards to the grading** and prevents the uninvestigated grid cells to receive very high score. This approach also has an ecological justification, especially for species which individuals use larger area (> 1 km^2) as their territory, i.e. the field observation may refer to individuals freely roaming across the wider area.

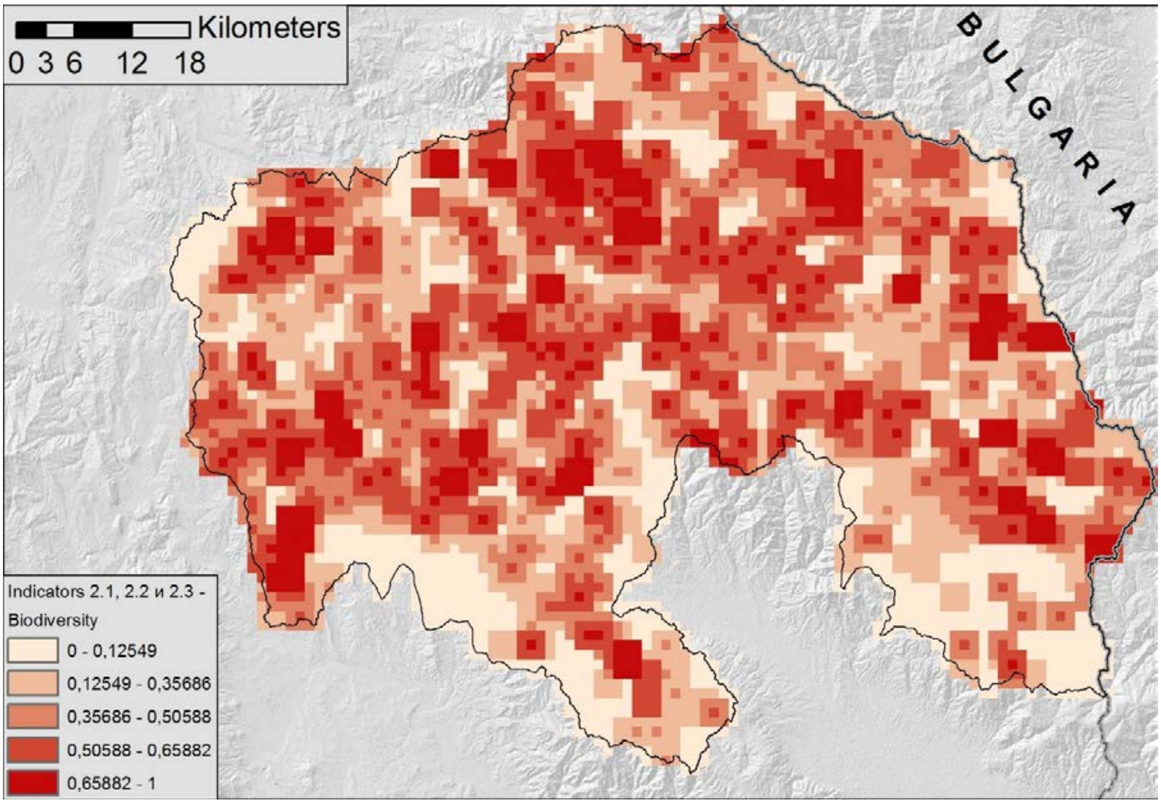

Figure 4. Map of the values of indicators 2.1, 2.2 and 2.3 - biodiversity

2.1.3 Criterion 3: Abiotic risks

Important Abiotic risks which can involve habitat patches defined by CLC2012, are risk of landslide (Restrepo et al., 2001), risk of fire (Vila et al., 2001) and wind impact (Visser et al., 2004).

2.1.3.1 Indicator 3.1: Landslide risk Indicator

Landslide risk can imply a change in species abundances and composition in habitats.

Calculations of the landslide risk index are based on European Environment Agency's "European Landslide Susceptibility Map" (1km2 resolution) - "ELSUS 1000 v1" (Gunther, 2014; Panagos, 2012; http://esdac.jrc.ec.europa.eu/themes/landslides).

The European Landslide Susceptibility Map is originally projected in LAEA/ETRS89 geographic coordinates. It was re-projected (in the UTM 34T/ WGS84 geographic projection) for the purpose of the landslide risk index calculation.

The landslide risk Indicator values are calculated as the mean value of the Landslide susceptibility map values that overlap each of the UTM grid cells (with area of 1 km2) (Fig. 5), taking the area of overlap into consideration, as well.

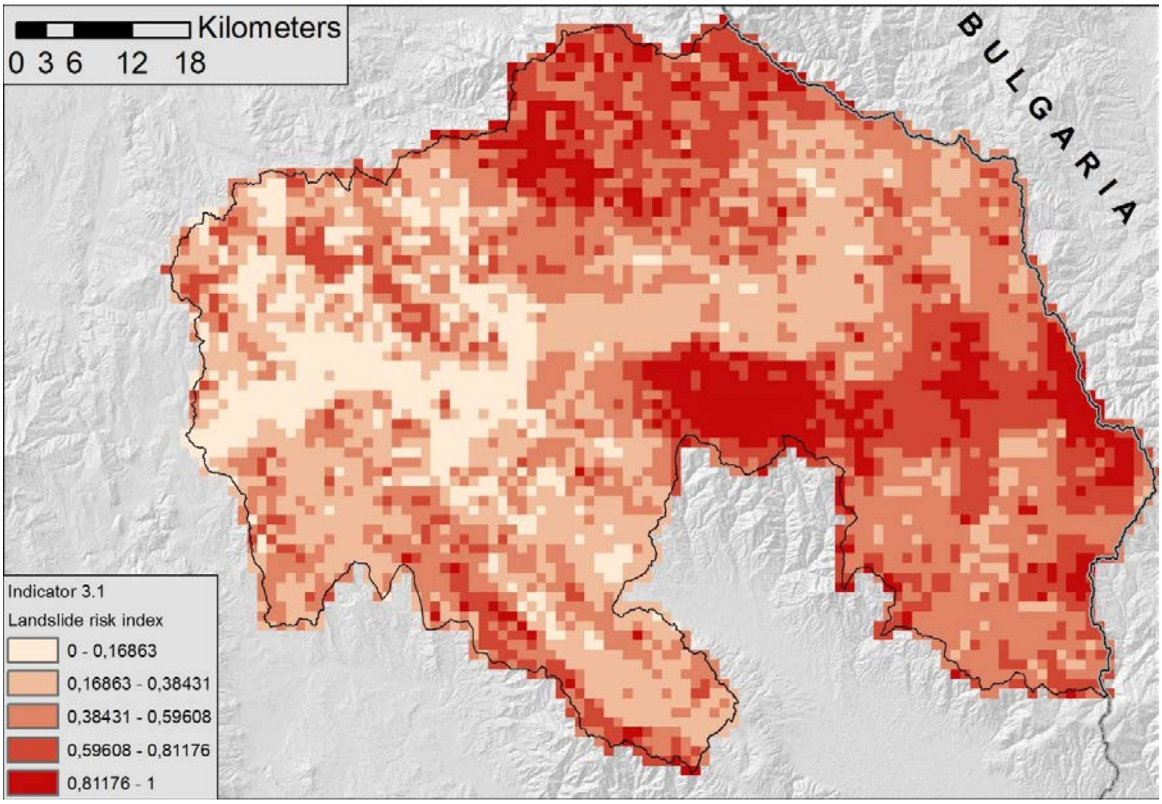

Figure 5. Map of values for the Indicator 3.1 – Landslide risk index

2.1.3.2 Indicator 3.2: Fire risk Indicator - Fire potential index (FPI)

The risk of fire is not the same for all habitats, but some factors make them more susceptible to this risk. Fire exposes a habitat to a chance of loss or damage of its ecological integrity, therefore it is closely connected to ecological sensitivity (Pecci, 2010).

The fire risk Indicator is computed using Fire Potential Index (FPI) (Burgan, 1988), which is calculated as: FPI = (1 - GVI) * (1 - WI), where GVI is the Greenness Index and WI is the Wetness Index (Crist and Cicone, 1984).

GVI and WI are calculated from the Landsat 8 satellite images (resolution 30m x 30m), with the use of the equations:

GVI = FG2 * B2 + FG3 * B3 + FG4 * B4 + FG5 * B5 + FG6 * B6 + FG7 * B7 and

WI = FW2 * B2 + FW3 * B3 + FW4 * B4 + FW5 * B5 + FW6 * B6 + FW7 * B7, where

"BX"- normalized value for the quantity of reflected electromagnetic waves in the frequency range "X", detected by the Landsat 8 sensors (Table 15)
"FGX" – factor for multiplication of Band "X", for GVI calculation,
"FWX" - factor for multiplication of Band "X", for WI calculation.
The B1, B8, B9, B10, B11 bands are not used for GVI and WI calculations

Table 15. Landsat 8 electro-magnetic Band

Band	Wavelength	Resolution
1 – Coastal aerosols	0.43 – 0.45	30
2 – Blue	0.45 – 0.51	30
3 – Green	0.53 – 0.59	30
4 – Red	0.64 – 0.67	30
5 – Near infra-red (NIR)	0.85 – 0.88	30
6 – Infra-red 1 (SWIR 1)	1.57 – 1.65	30
7 – Infra-red 2 (SWIR 2)	2.11 – 2.29	30
8 – Panchromatic	0.50 – 0.68	15
9 – Cirrus	1.36 – 1.38	30
10 – Thermal infra-red 1 (TIRS 1)	10.60 – 11.19	100 * (30)
11 – Thermal infra-red 2 (TIRS 2)	11.50 – 12.51	100 * (30)

The multiplication factors for calculation of GVI and WI are shown in Table 16 (Baig, 2014).

Table 16. Multiplication factors for Landsat 8 Bands, used for GVI and WI calculations

For the Landsat 8 Band	**B_2 (Blue)**	**B_3 (Green)**	**B_4 (Red)**	**B_5 (Near Infra-red range - NIR)**	**B_6 (Infra-red 1 - SWIR1)**	**B_7 (Infra-red 2 - SWIR2)**
Factors	**F_2**	**F_3**	**F_4**	**F_5**	**F_6**	**F_7**
Greenness (G)	-0,2941	-0,2430	-0,5424	0,7276	0,0713	-0,1608
Wetness (W)	0,1511	0,1973	0,3283	0,3407	-0,7117	-0,4559

The Fire risk Indicator values are calculated as the mean value of all calculated FPI pixels (Landsat 8 - area 900m2) that overlap with each of the UTM grid cells (area 1 km2) (Fig 6). These values are normalized in the range [0 - 1]

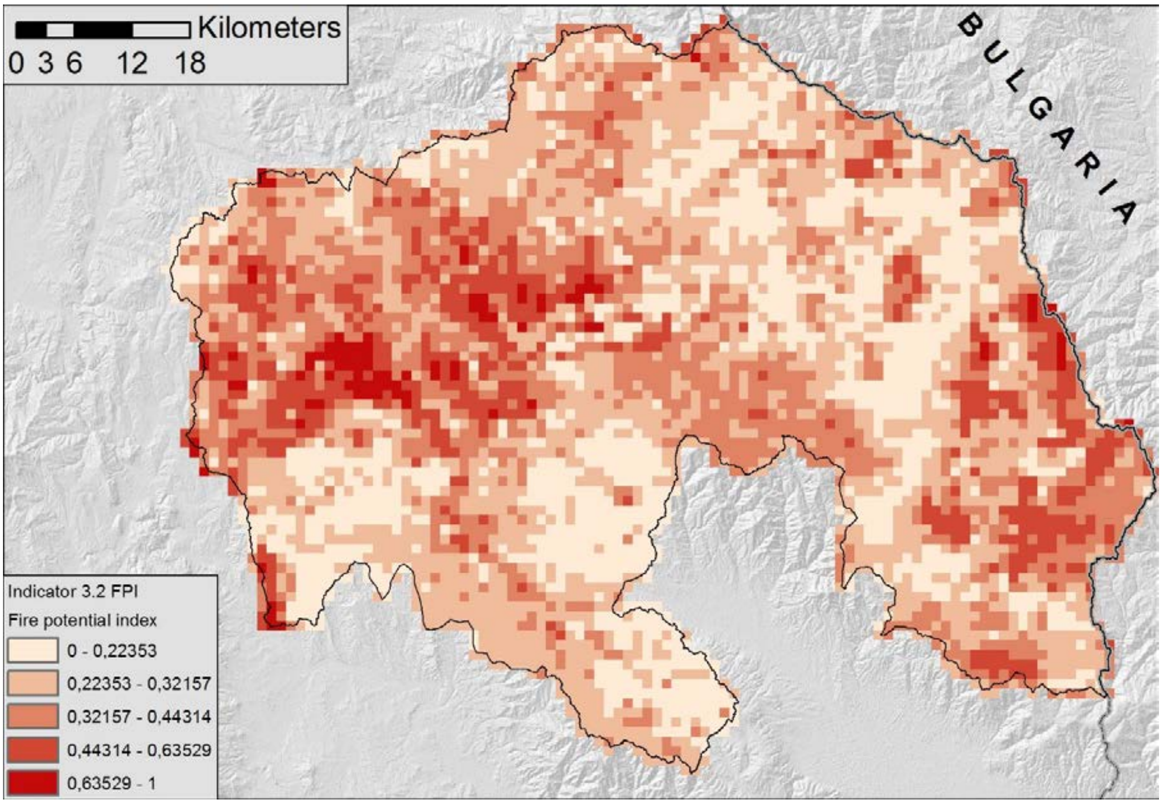

Figure 6. Map of values for the Indicator 3.2 – Fire potential index (FPI)

2.1.3.3 Indicator 3.3: Habitat aspect (orientation) compared to the main wind direction Indicator

Wind impact upon habitat is measured as a value ranging from 0 to 1, where 0 represents the orthogonality between the prevailing wind and the habitat orientation, and 1 represents the parallelism between the prevailing wind and the habitat orientation involved. Wind carries parallel accelerated soil erosion, damage to vegetation, and changes in biological communities, and affects more habitats which are oriented parallel to prevailing wind (Pecci, 2010).

The ASTER GDEM (Aster GDEM, 2011) digital elevation model was used for determination of the habitat orientation. The pixel resolution of the ASTER GDEM is 1 arc second (~30m x 24m in the studied area). Prior to the calculations, the geographic projection of DEM was transformed from WGS84 to WGS84 / UTM 34T (square areas of pixels).

The habitat aspect model (terrain orientation) was generated (24m x 24m pixel resolution, aspect values in degrees) with “Spatial Analyst” tools for ArcGIS 10.2 (ESRI, 2013), using the re-projected DEM.

The main wind orientation data was based on public access data for the direction and velocity of winds that occurred in June 2015, at a height of up to 10m from the surface, generated by the National Hydrological and Meteorological Services of Republic of Macedonia. The data was additionally processed using “Krieging” interpolation, in order to obtain adequate data on general direction of the wind, in higher resolution (1km2) than the available, that also fits the UTM grid used for the sensitivity map.

The values this Indicator receives are in the range [0 - 1]. In the first step, they are calculated for every pixel of the DEM (area 576m2) with the equation:

IWIND = sin {abs [(α mod 180) - (β mod 180)]}, where:

α - Terrain aspect angle;
β - Main wind direction angle;
"Mod 90" - function used for calculating the residue after division with the value "90";
"Abs" - function used for calculating the absolute value of the subtraction.

These functions are used because the Indicator values represent orthogonality and parallelism of the terrain aspect and the wind direction.

In the second and final step, the "Habitat orientation compared to the main wind direction" Indicator values are calculated as the mean value of all calculated IWIND pixels (DEM - area 576m2) that overlap with each of the UTM grid cells (area 1 km^2) (Fig 7).

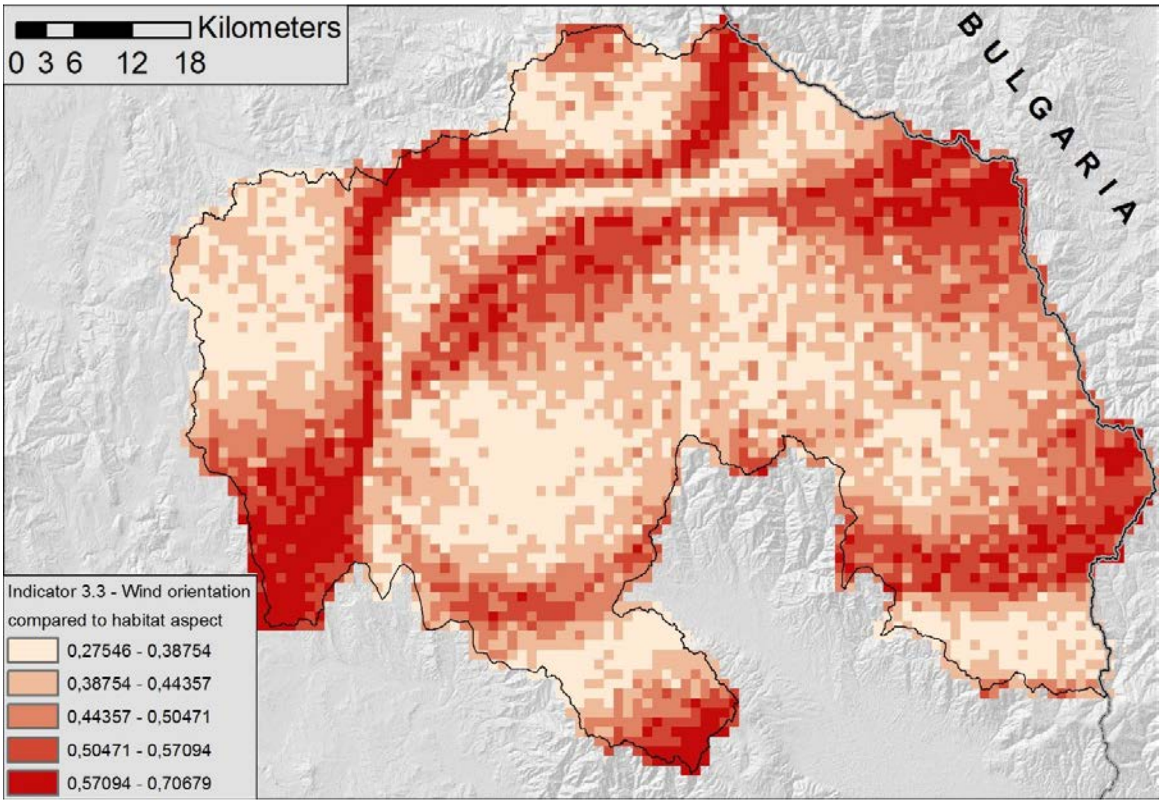

Figure 7. Map of values for the Indicator 3.3 - Habitat orientation compared to the main wind direction

2.1.4 Criterion 4: Habitat patch isolation (connectivity, corridors and core patch importance)

2.1.4.1 Indicator 4.1: Presence of corridors that connect the core patches for forest species (4.4 – steppe species, 4.7 – high mountain species).

The corridors are defined using "cost-distance" analysis with the software package "ArcGIS" (ESRI, 2011) and "Graphab" (Foltete, 2012), as the shortest paths, i.e. paths with "minimal passing weight" which are connecting the core patches in the researched area, taking into consideration the types of habitat patches through which they pass.

The data from the "CORINE Land Cover 2012" (CLC2012) are used for defining the habitat patches.

Categories 311, 312 and 313 are used as core patches during the analysis of forest inhabiting species. These CLC2012 are forest categories with minimal value (value “0”) for the “Impermeability” factor for the forest species (Table 17).

Categories 231, 321 and 333 are used as core patches for the steppe species (pastures, natural grasslands and areas with sparse vegetation), if the terrain altitude (ASTER, 2011) is also under 750 m above sea level (a.s.l.). Additionally, all the habitats above 750m a.s.l. are given the highest value for the Impermeability factor (most difficult to be used as a corridor), regardless of CLC2012 category.

The high-mountain species use the same CLC2012 categories as core patches as the steppe species, but only if the patches are located above 1400 m a.s.l. Additionally, all the habitat patches below 1400m a.s.l. are given the highest value for the Impermeability factor for the high-mountain species, regardless of CLC2012 category.

The Impermeability factor values are taken into account during the calculation of the total “weight” of each corridor. Although the corridor weight is linearly dependent with its length, it is higher if the corridor stretches through less “permeable” habitat patches. As an example, the corridors that are stretching through habitats with low permeable values, have their calculated “weight” to be less than their length. On the other hand, the corridors that are stretching only through habitats with the highest factor of impermeability, have their calculated “weight” identical to the value of the length.

Each group of species is analyzed separately. This is to be expected given the fact that there are differences in the core patches and the habitat Impermeability factors (Table 17).

The values of this Indicator on the sensitivity map is calculated in three steps. The first step is calculation of the sum of the products of the “weight values” of the corridors and the length of the segments with which each corridor enters in a given cell from the UTM coordinate grid (1km2 area). The calculated values are then processed with a logarithmic function, and finally are normalized in the range [0 - 1] (Figures 8, 9 and 10).

All corridors are taken into account during the analysis of the forest species. However, in the analysis for the steppe species corridors, only the corridors with a length less than 3000m are taken into consideration, whereas in the high-mountain species analysis, only the corridors with lengths less than 2000m are taken into account.

The corridors are calculated as ideal lines connecting the core patches using the shortest, i.e. the “the easiest” paths. In the calculations for the Indicator values, the corridors are treated as polygons with a 1 km width around their already defined ideal line in both directions (1km buffer). By doing so, the influence of one corridor is also enlarging “the value”, i.e. sensitivity on the neighboring cells of the UTM grid and not only the cells through which the corridors is ideally passing. This way, a more realistic valorization of the space is obtained because the corridors are threated in a form closer to the reality. Also, increased sensitivity of the locations where most probable alternatives of the ideal corridors are found is achieved during the calculations. They wouldn’t be taken into account during the calculations otherwise.

Table 17. Impermeability factors of CLC2012 categories represented in the Bregalnica watershed used during the habitat connectivity analysis for the forest, steppe and high-mountain species.

CORINE Land Cover 2012 (CLC2012)		Factor of Impermeability$_{CLC}$ [0 - 1]	
Code	**Name of category (Label 3)**	**Forest species**	**High-mountain and steppe species**
112	Discontinuous urban fabric	0,95	0,95
121	Industrial or commercial units	0,95	0,95
131	Mineral extraction sites	0,95	0,95
132	Dump sites	0,95	0,95
133	Construction sites	0,95	0,95
211	Non-irrigated arable land	0,8	0,2
213	Rice fields	0,8	0,5
221	Vineyards	0,4	0,3
222	Fruit trees and berry plantations	0,4	0,4
231	Pastures	0,5	0
242	Complex cultivation patterns	0,7	0,1
243	Land principally occupied by agriculture, with significant areas of natural vegetation	0,3	0,1
244	Agro-forestry areas	0,2	0,7
311	Broad-leaved forest	0	0,99
312	Coniferous forest	0	0,99
313	Mixed forest	0	0,99
321	Natural grasslands	0,4	0
323	Sclerophyllous vegetation	0,5	0,1
324	Transitional woodland-shrub	0,2	0,2
331	Beaches, dunes, sands	0,9	0,1
332	Bare rocks	0,9	0,1
333	Sparsely vegetated areas	0,6	0
512	Water bodies	1	0,8

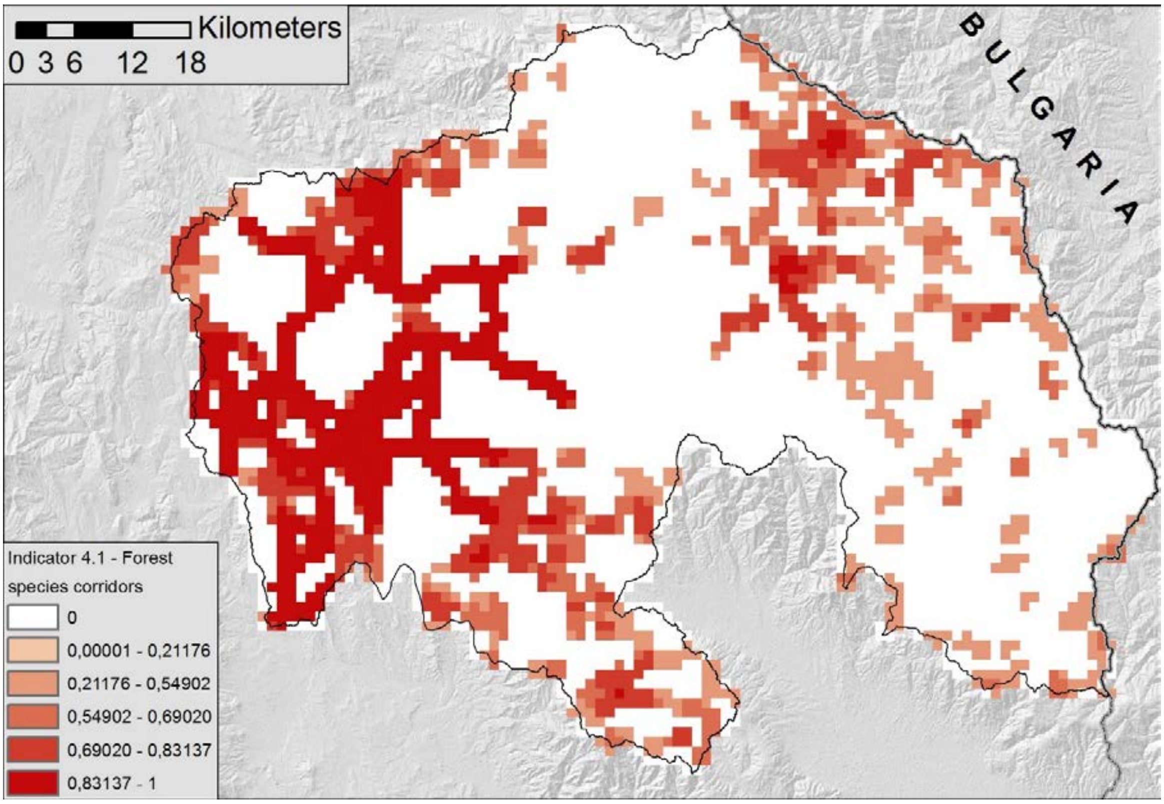

Figure 8. Map of values for the Indicator 4.1 – presence of corridors connecting the core patches for forest species

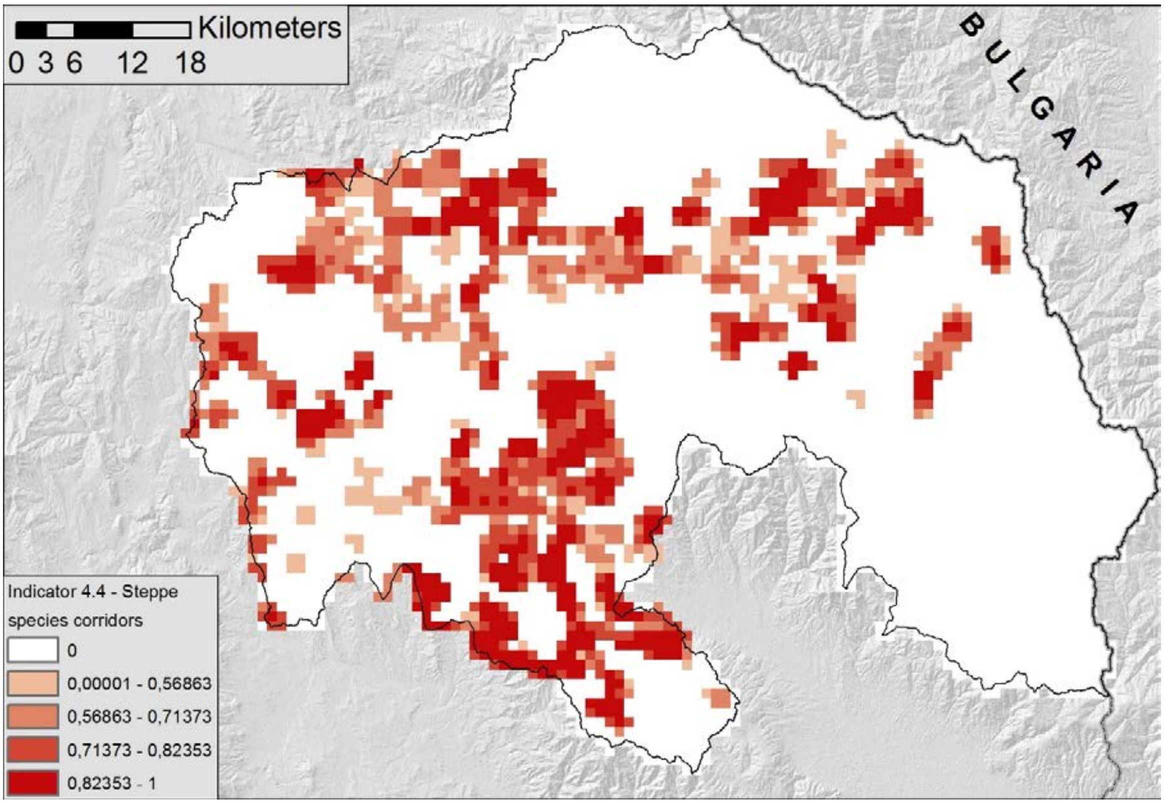

Figure 9. Map of values for the Indicator 4.4 – presence of corridors connecting the core patches for steppe species

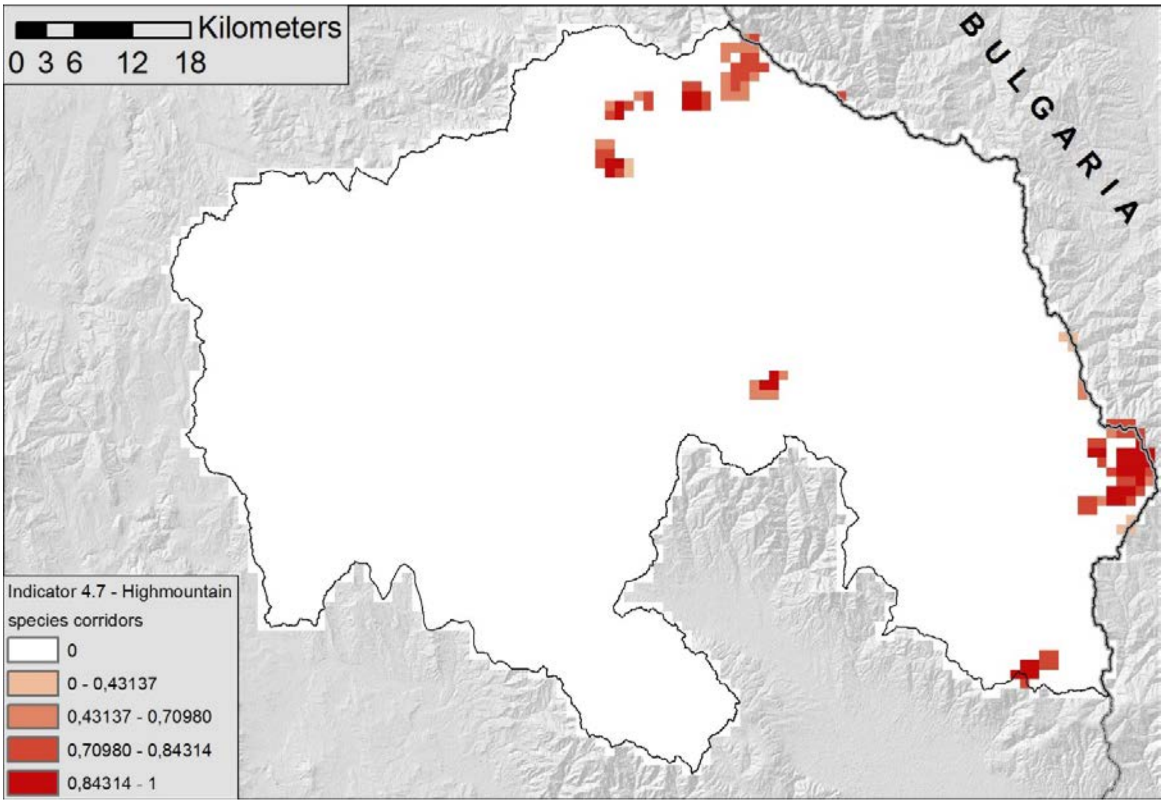

Figure 10. Map of values for the Indicator 4.7 – presence of corridors connecting the core patches for high-mountain species

2.1.4.2 Indicator 4.2: Presence of habitat patches, categorized according to their influence on core patch connectivity in the study area, from the perspective of the forest species (4.5 – steppe and 4.8 high-mountain species).

All habitat categories are not equally important for the connectivity of the core patches for a given species. Also, one habitat category has different importance for the connectivity of the core patches, for the different species groups. In the computations, this "importance", or rather, lack of importance is represented with the factor of impermeability (Table 17).

The CORINE Land Cover 2012 categories are used for describing the habitat categories.

The terrain altitude (ASTER GDEM, 2011) is additionally used in the habitat connectivity evaluation, but only in the analysis regarding the steppe and the high-mountain species groups.

In the case of the steppe species, all habitat patches above 750m a.s.l., and in the case of high-mountain species, all patches below 1400m a.s.l. are given the largest Impermeability factor, regardless of CLC2012 category.

The Indicator is calculated as a product of the surface representation of the habitat patches (in km2) in each cell of the UTM grid (with a surface of 1 km2) and their respective importance (permeability) factors Permeabilityclc = (1 – ImpermeabilityCLC).

The maps with the values for the appropriate Indicators for all analyzed species groups are given in Figures 11, 12 and 13.

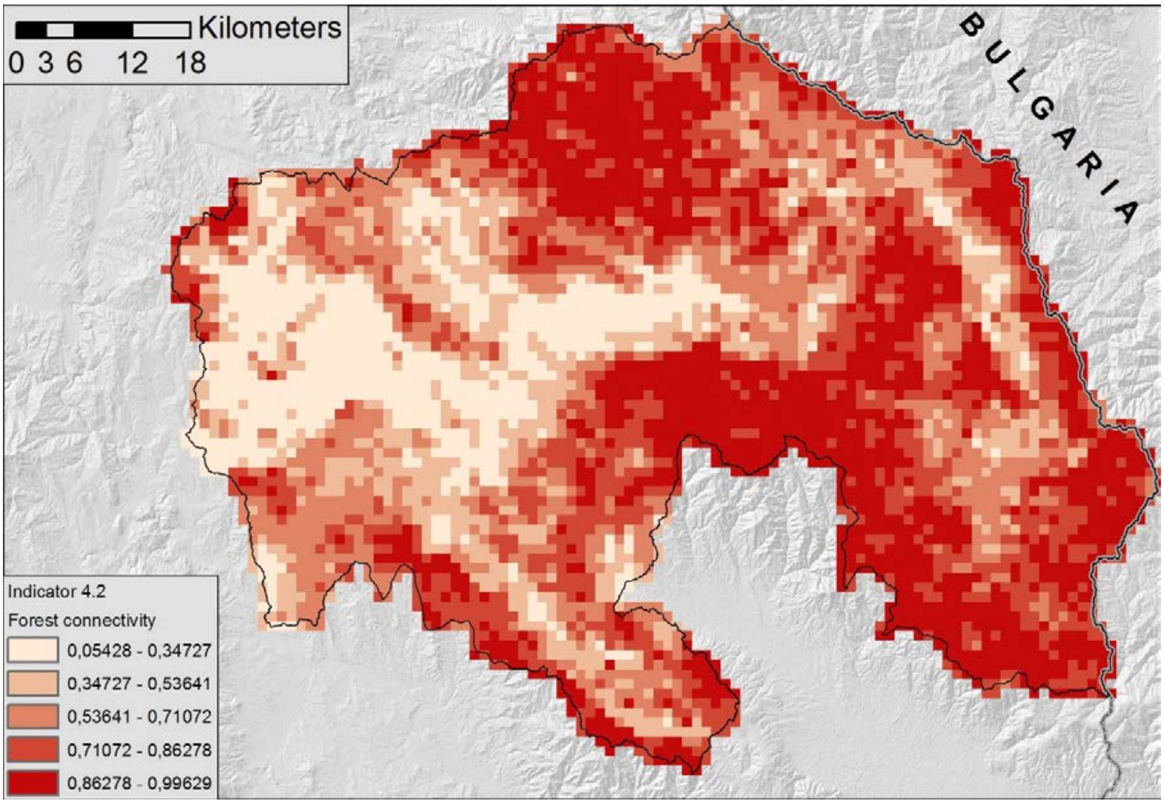

Figure 11. Map of values for the Indicator 4.2 – presence of habitat patches categorized according to their importance for connectivity of the core patches for forest species

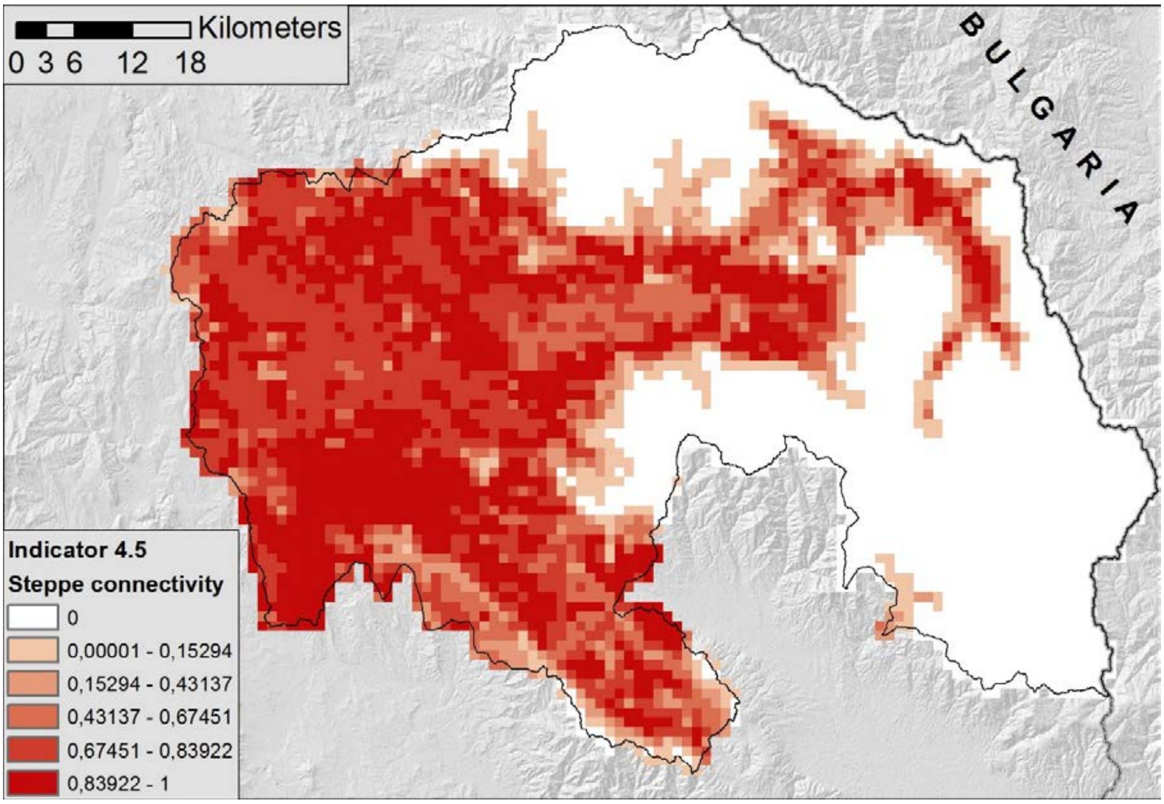

Figure 12. Map of values for the Indicator 4.5 – presence of habitat patches categorized according to their importance for connectivity of the core patches for steppe species

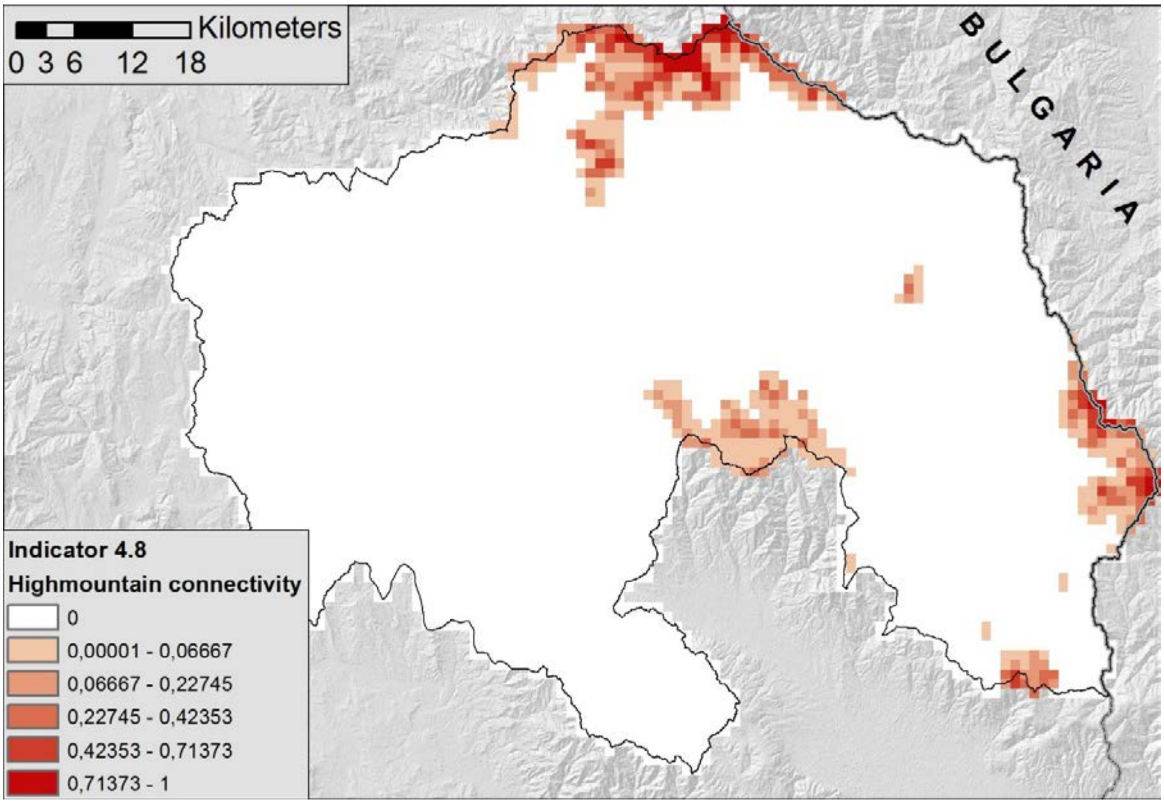

Figure 13. Map of values for the Indicator 4.8 – presence of habitat patches categorized according to their importance for connectivity of the core patches for high-mountain species

2.1.4.3 Indicator 4.3: Presence of core patches for forest species (4.6 – steppe and 4.9 – high-mountain species), categorized according to their overall importance for the connectivity of the whole study area

Not all core patches are equally important for the overall connectivity of the researched area. By using the "Delta Probability for Connectivity – DeltaPC" analysis in the software package "Graphab", the core patches for each species group are analyzed separately, and valued accordingly. The evaluations are based on the calculation of the overall loss of connectivity effect in the whole study area, in cases of inexistence or destruction of each of the separate core patches.

The CORINE Land Cover 2012 categories are used for describing the core patches, as the areas with the zero values for the Impermeability factor (Table 17).

The terrain altitude (ASTER GDEM, 2011) is additionally used in the determination of the core patches, but only for the steppe and the high-mountain species groups. In the case of the steppe species, core patch habitats can only be found below 750m a.s.l., and in the case of high-mountain species, core patch habitats can only be found above 1400m a.s.l.

The Indicators are calculated in four steps. In the first step, a sum of the products of the surface representation (in km2) of all core patches which are found in a given cell of the UTM grid (with a surface of 1 km2) and their respective DeltaPC indices are calculated. The obtained null values are not processed in the further steps, and the positive (non-null) values are multiplied with a factor large enough, so that the smallest non-null value becomes larger than 1. In the third step, these values are processed with logarithm function. Finally, in the fourth step, the non-null values are normalized in the [0-1] range.

The maps with the values for the appropriate Indicators for all analyzed species groups are given in Figures 14, 15 and 16.

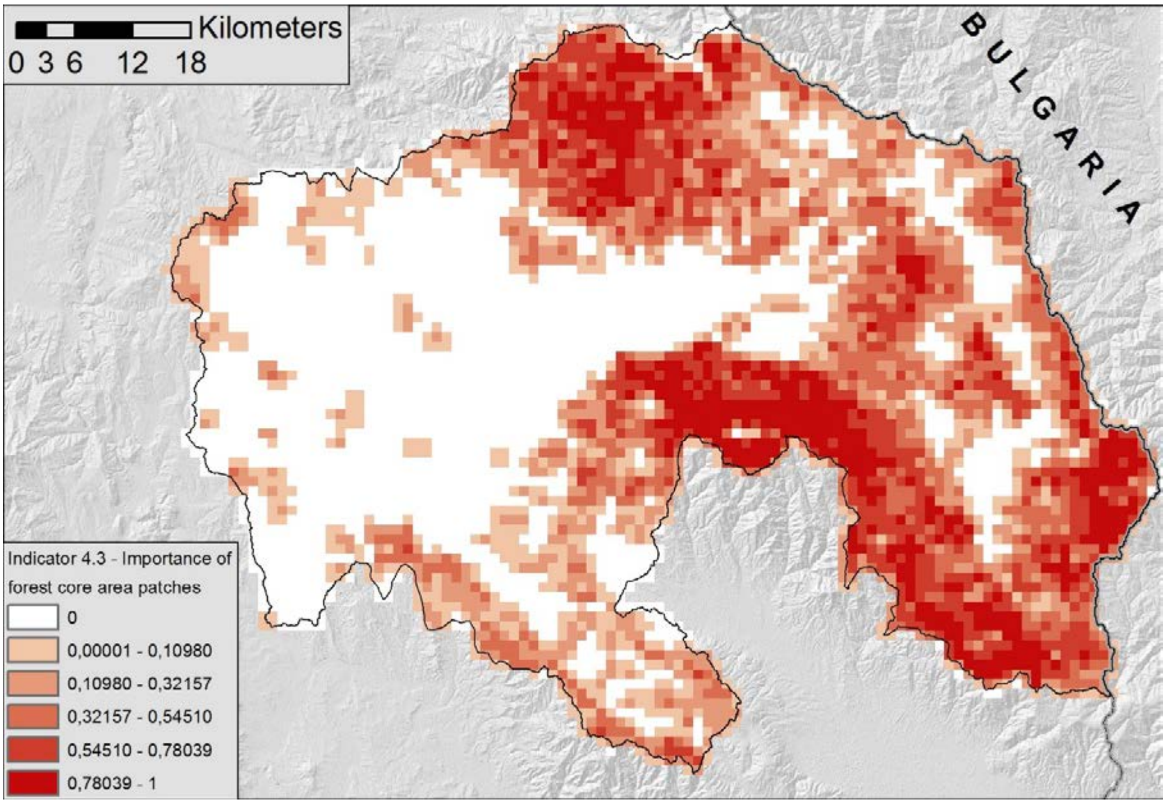

Figure 14 – Map of values for the Indicator 4.3 – presence of core patches for forest species, categorized according to their significance for the overall connectivity in the study area

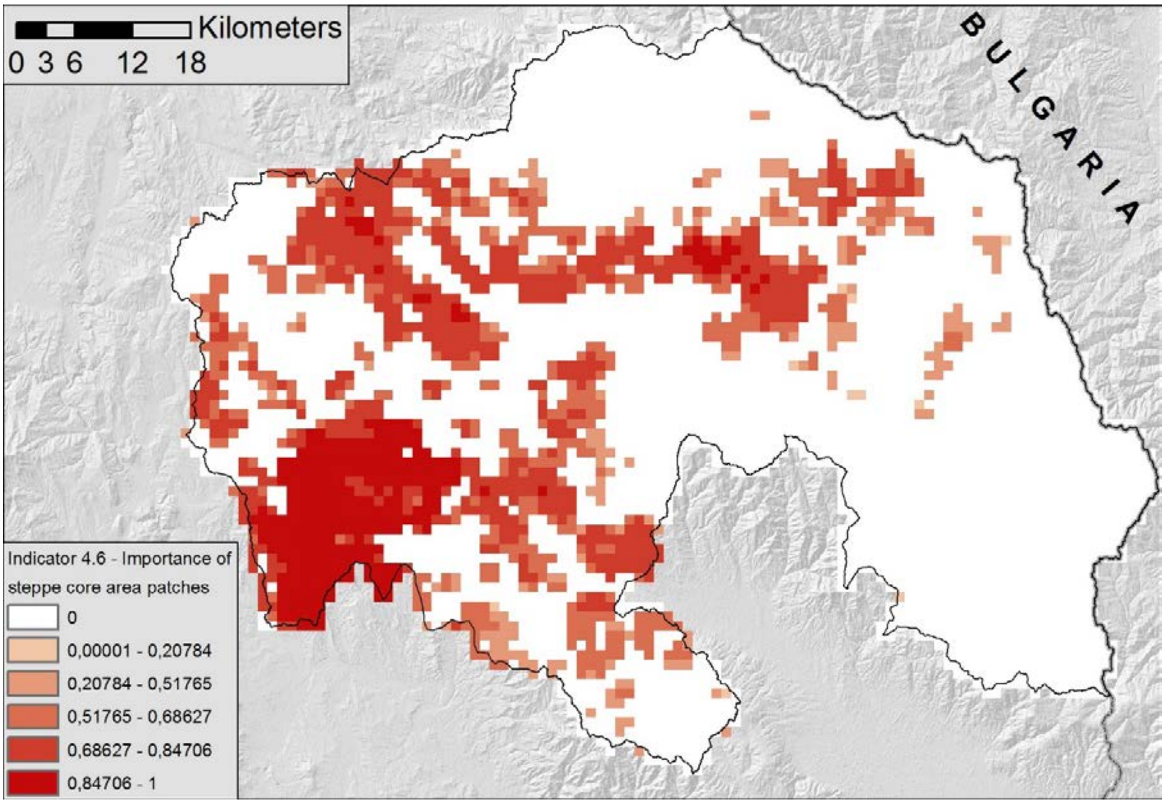

Figure 15. Map of values for the Indicator 4.6 – presence of core patches for steppe species, categorized according to their significance for the overall connectivity in the study area

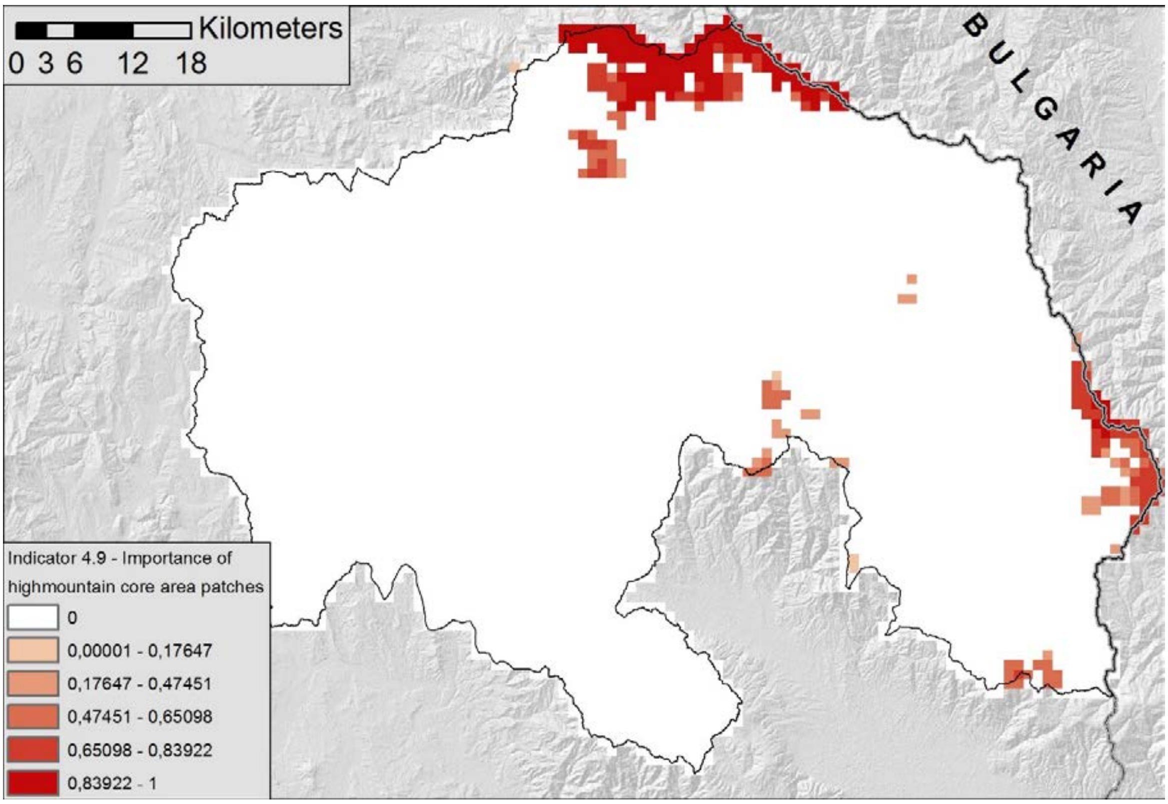

Figure 16. Map of values for the Indicator 4.9 – presence of core patches for high-mountain species, categorized according to their significance for the overall connectivity in the study area

2.2 Calculation of the Ecological Sensitivity map values

The Ecological Sensitivity map (Figure 18) is calculated as the mean value of each of the indicators, calculated for each cell of the UTM grid (area 1 km2). The “Raster calculator” tool in ArcGIS was used for this calculation (Figure 17). The division into sensitivity classes was done according to the Jenks natural breaks classification method (Jenks 1967).

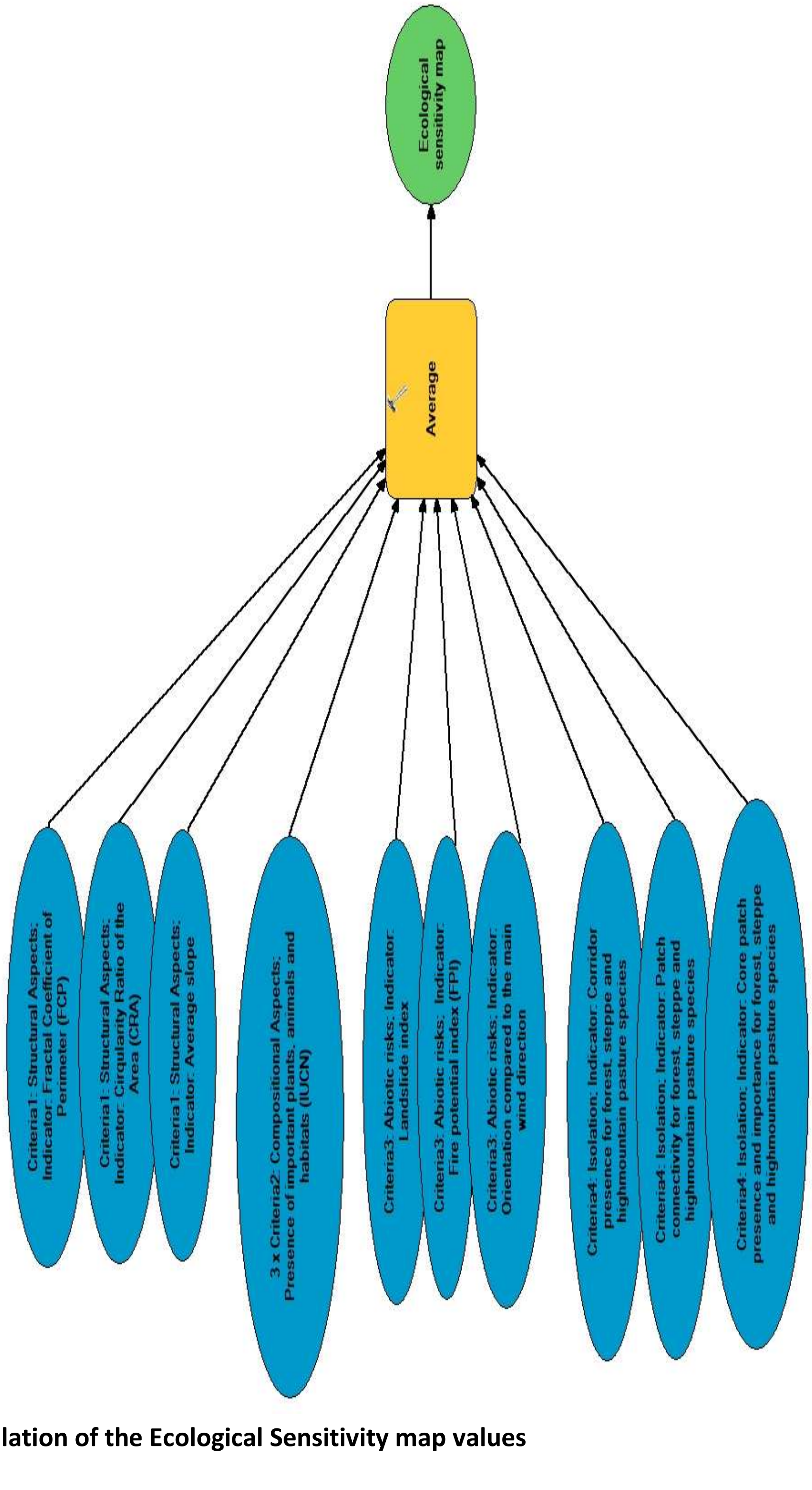

Figure 17. Calculation of the Ecological Sensitivity map values

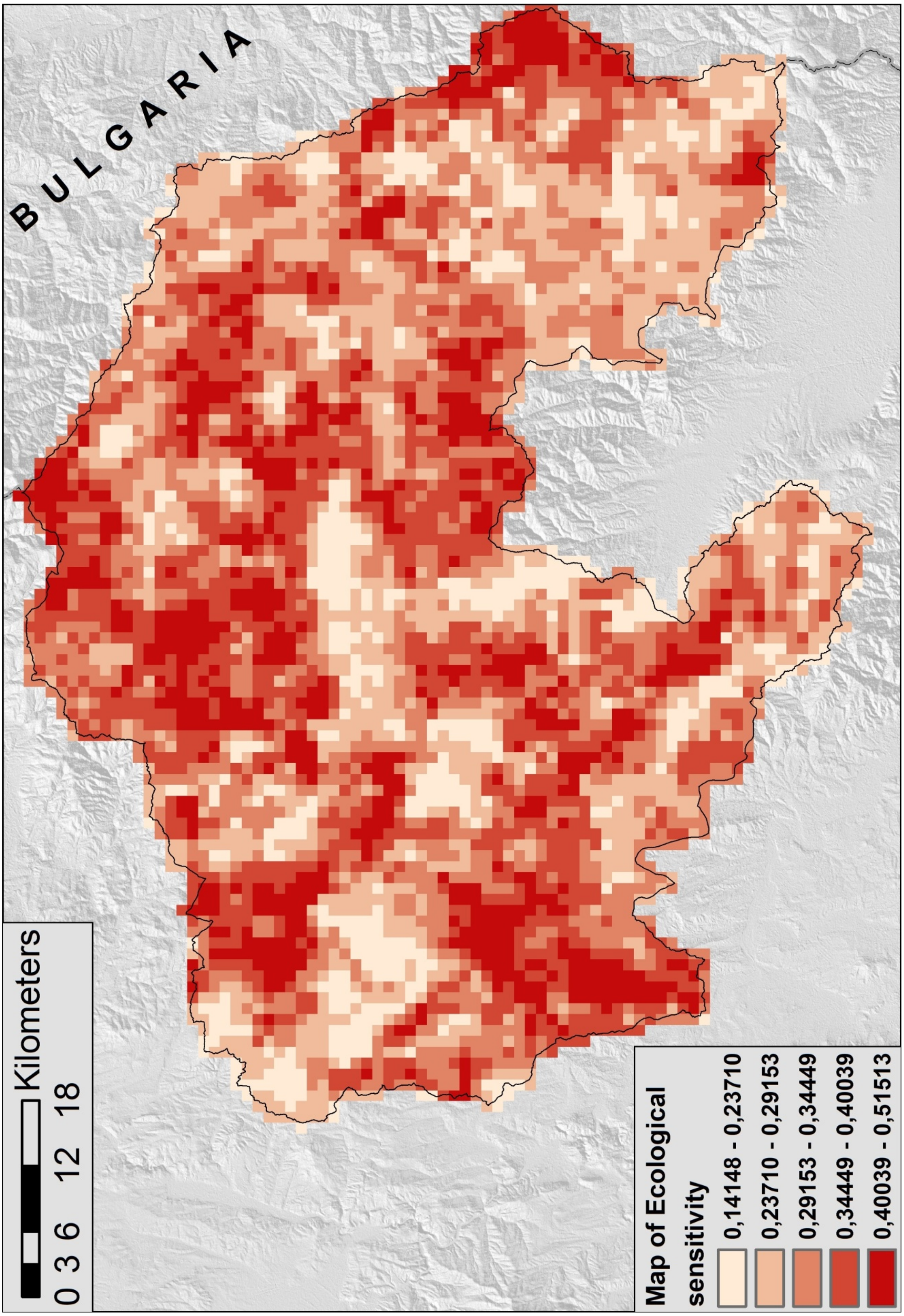

Figure 18. Ecological Sensitivity Map

3 Analyzes of Ecological Sensitivity Map and Recommendations

The Ecological Sensitivity Map integrates the data on the biological diversity and its conservation values, the existence of core patches in different habitat types, the functionality of the bio-corridors, and the factors affecting the biodiversity that are originating from the innate nature. The most sensitive areas in the Map are those that have highest values from aspect of the biodiversity and are in the same time under the highest risk due to unfavorable abiotic factors. In the same time, the most sensitive areas are very often core areas for the most important animal and plant species. Therefore, priorities for their protection are preservation of their functionality and connectivity – or, in other words, they are the most important areas for conservation. The least sensitive areas are those with lowest values for the biological diversity and under low risk of the abiotical factors. Between these end-points are the areas where the biodiversity values are high, but are not threatened, and the areas with relatively lower biological values, being under significant risk from the abiotic factors.

The number of the individual UTM squares (1x1 km^2) classified in the one of the five sensitivity categories shows a relatively small portion of highly-sensitive regions (slightly above 10% of all squares), but a large part of the squares is evaluated as medium to highly sensitive. Part of them might easily shift in the higher category with improved surveys. These two categories together make a bit more than one third of the total area of Bregalnica river watershed, indicating the relatively high importance of the entire region for conservation of the biological diversity. They provide general directions for selection of priority areas for future conservation work, but one should bear in mind that even the lower-ranked regions need further research.

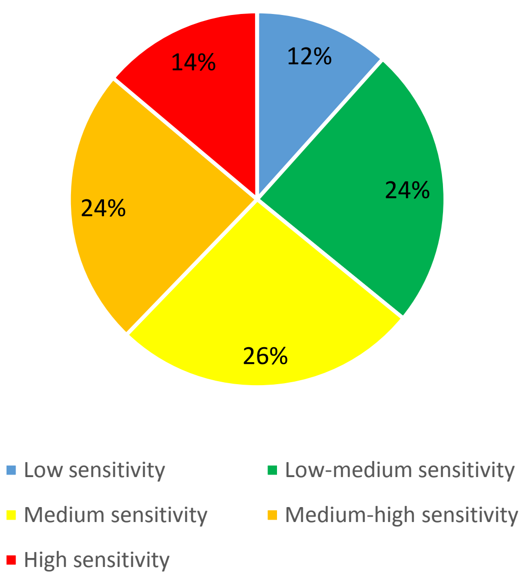

Figure 19. Percentual participation of quadrants according to their sensitivity level.

One should bear in mind that data for the biological diversity have not been equally available for the entire region. The methodology used overcomes this problem to a large degree, but there is still real possibility that the sensitivity of some regions is underestimated. On the other hand, the survey was focused on the proposed protected areas, which likely result with their relatively highly estimated sensitivity.

The general recommendations for biodiversity protection are given in the report for the **Biodiversity in Bregalnica Watershed (book 2)** and the separate expert reports. They summarize the most important sectors which affect the nature and the biological diversity, and are specific for given group of plants, animals, fungi and habitats. The analysis of the Ecological Sensitivity Map gives some recommendations and directions for conservation measures that are complementary the recommendations of designation of new protected areas, management of habitat and species, etc.

-

The following regions can be pinpointed as the most sensitive:

- Lower Bregalnica – with domination of the steppe-like habitats with high and specific biological diversity. The main risks include the aeolian and hydro erosion, and the natural succession towards forest.
- The mountainous and high-mountainous parts of Osogovo Mts. (Carev Vrv – Ruen) and Maleshevo Mts. The most important values of these regions are the preserved and connected forest ecosystems, presence of forests with conservation values and the high diversity in the high-mountain zone. Forests are the main threats.
- Mangovica – this area is important due to the presence of valuable habitat types and threatened bird species, and other important species. The main risks come from the succession and encroachment of the open habitats, and to lesser degree the risk of fire and other abiotic factors.
- The valley of Kriva Lakavica river and Mantovo reservoir – this area is characterized by presence of important habitats along Kriva Lakavica river and the large number of wetland birds and birds of prey.
- Zletovska Reka river – Ratkova Skala – the region is characterized with high biological diversity in more biological groups, including important bird species. The main risks are due to the large inclination and land-slides (leading to erosion) the fragmentation of the forest ecosystems etc.
- Golak – the high sensitivity is due to the important biological diversity, and the risks of forest fires.
- Plachkovica Mt. – is characterized by important steppe-like habitats in the lower sections and preserved forest ecosystems with threatened/specialized species in the higher parts. The main risks are due to the high fragmentation level, inclination and the risks of land-slides, and to the lesser extent, the possibility of forest fires.

3.1 Proclamation of Protected Areas

The new Protected Areas Proclamation Process is complex and requires development of special valorization studies from relevant ministerial bodies and public enterprises, as well as active participation on behalf of the local stakeholders and municipal authorities. In the moment, we can’t talk of any re-proclamation of protected areas in the watershed region because it only applies to the “Murite” Protected Area. The remaining protected “areas” are consisted mostly of individual tree trunks and one paleontological locality, which are recommended to be proclaimed as "Natural Rarities" (advise the **Report on the Status of Protected Areas, Book 4**).

No matter how isolated, the protected areas are the basis for nature and biodiversity protection for the Bregalnica River Watershed. Hence, it's crucial to develop a Strategy based on the Eastern Planning Region's Spatial Plan and Report on the Status of Protected Areas where protected areas priorities are identified, along with the proclamation process dynamics. It's evident that Eastern Planning Region municipalities have no experience in protected area proclamation and their function. These are the reasons why it's best to have the first phase of new protected area proclamation along with development of Protected Area Management Plans and their implementation. For this first phase of the proclamation process several suitable areas can be endorsed, located in the lower flows of the Bregalnica River. These areas have small economic potential and with tat the main potential conflicts are evaded. Interestingly enough, at the same time these areas hold high biodiversity values, unique on both national and European level. The areas corresponding to this description are "Dolna Bregalnica", "Mangovica", "Gladno Pole", "and Gjuzumliska Reka", "Dolna Zletovica", "Sokolarci and Ovche Pole". Understandably, for the proclamation of these new protected areas it's important to work with farmers and other relevant stakeholders.

Protection of Osogovski Planini Mts. is a process implemented on behalf of Macedonian Ecological Society, since 2007. Although this process's main goal (of proclamation of Protected Landscape and Cross-border Biosphere Reserve) isn't met yet, many more nature protection results were accomplished, such as: detailed biodiversity and other natural values data inventory, socio-economic parameters, extensive Public Awareness Campaign, tourist promotion, initial forest certification, cross-border collaboration, etc. Therefore, it's crucial to continue with process and to establish a collaboration between nature Protection Programme and Macedonian Ecological Society.

In the first phase, it's possible to proclaim some of the protected areas which primarily have geomorphological values (Kukuljeto, Machevo) and can easily be used for tourism purposes.

Proclamation of protected areas with predominant forest features is a process that needs to be implemented gradually, in close collaboration with PE Macedonian Forests and respective regional offices. Hence, it's recommended to have the proclamation of these areas in the second proclamation phase, although preparatory activities can commence earlier (high natural value forests identification, forests certification, forest produce use assessment). These type of areas have small surface and refer to well-kept forest units (Kartal, Adjinica, Temniot Andak, Salandzhak, Crvena Reka, etc.).

Last Protected Area Proclamation phase should include the big and more complex areas. This refers to Chengino Kale, Zrnovska Reka-Lisec, etc.

The Protected Area Proclamation process should go along with intensive Public Awareness Campaign, development of case studies, establishing and maintaining collaboration with other protected areas from Macedonia and abroad, etc.

3.2 Conservation Action Plans

Protected Area Proclamation is a good basis for biodiversity protection, but it also is a tool to provide the protected area's efficiency. As an example, apart from the proposed Protected Landscape "Osogovski Planini Mts.", none of the rest is good enough to provide protection of the populations of some large carnivores and/or birds.

Therefore, it's important to select the key species to develop Conservation Action plans for. Such species are resented in the report on **Biological diversity in the Bregalnica River Watershed (Book 2)** and the separate experts' reports. Species selection should be based on severely criteria, such as threat status, distribution, habitat preference and on the **Ecological Sensitivity Map (Book 5)**. Primarily, key species to be included are large carnivores (Wild Cat, Roe Deer, Jackal), bats, raptor bird species, (Imperial Eagle, Egyptian Vulture, Lesser Kestrel etc.), and some other birds (Black and White Stork), tortoises, xylophagous insects, other preserved forest specialist insects etc. With it, main activities should be towards protection of key species' core areas, as well as proper biocorridor management.

Apart from the key species, Conservation Action Plans can be implemented for specific habitats as well. Such specific habitats are the halophytic habitats of Ovche Pole and Slan Dol, lowland and mountain meadows, small wetland patches etc.

3.3 Species reintroduction

Several species are extinct from the Bregalnica River Watershed (Great and Little Bustard, Black Vulture, Balkan Lynx), and with some a serious population decline or sporadic presence is identified (Egyptian and griffon Vulture, Brown Bear). One of the ways to improve the state of the biodiversity is species reintroduction. At this moment, we can freely declare that there are no conditions for reintroduction to any of the abovementioned species. According to the natural areal, the Bregalnica River Watershed can only be used for reintroduction of the Black Vulture and the Little Bustard. Before these birds are reintroduces, specific long-term reintroduction plans need to be prepared.

The Bregalnica River Watershed isn't a priority region for Balkan Lynx and Brown Bear reintroduction, given that the stronghold of their natural populations is situated in Western Macedonia. Also, local communities will have a difficult time accepting reintroduction of a species they haven't had contact with for a longer period of time.

3.4 Biocorridors management

Biocorridor management guidelines are provided in the Brown Bear Corridor Management Plan, as integral part of the "Developing National Ecological Network of R. Macedonia (MAK-NEN)" project (Brajanoska et al. 2011). Corridors identified to be of the watershed's interest are Smrdesh, Smrdesh-Goten, Goten, Malesh. Vlaina Planina Mt., Istibanja, I parts of Osogovski Planini Mt.-German and Deve Bair. Apart from these predominantly forest biocorriodors, several steppe biocorridors are identified too and they are as follows: Kampur, Karatmanovo-Ivankovci and Stip corridor. The MAK-NEN identified biocorridors and core areas are to some extent confirmed with the Ecological Sensitivity Map, too.

The Ecological Sensitivity Map is a more sophisticated tool to determine the forest, “steppe” and high-mountain corridors, and in this context provides precise geographic focus with the implementation of the Corridor Management Measures.

3.5 Biosphere Reserves

Osogovski Planini Mt. are proposed as an area to establish a cross-border Biosphere Reserve. So far, a Feasibility Study is prepared and many national and international consultations were undertaken.

The area of lower Bregalnica is a unique for its high biodiversity values. Human activities are predominantly extensive with use of many traditional practices. This area too is a good candidate to be stablished as a Biosphere Reserve. The only precondition to start proclamation of any area as Biosphere Reserve is to proclaim one or several smaller protected areas with core area values within the boundaries of the Biosphere reserve first.

4 References

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