ANALYSING LANDSCAPE FRAGMENTATION AND CLASSIFYING THREATS FOR HABITATS OF COMMUNITY INTEREST IN THE "IRON GATES" NATURAL PARK (ROMANIA)

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ABSTRACT

Our study aims at evaluating the ecological impact of landscape fragmentation, identifying, and classifying the threats affecting habitats of community interest in the "Iron Gates" Natural Park. We used landscape metrics for assessing the fragmentation process, results expressing decreases in the values of three metrics (MPS, ED, SDI) and increases for two metrics (NumP and IJI). We observed an insignificant increase in landscape fragmentation related to a reduced decrease of its landscape diversity for the 1990-2006 timeframe. We classified the main anthropic threats to habitats of community interest in three main categories: diversification and densification of buildings and transportation infrastructures, land use and industrial activities.

RÉSUMÉ: Analyse de la fragmentation du paysage et classification des menaces pour les habitats d'intérêts communautaires dans le Parc Naturel des "Portes de Fer" (Roumanie).

L'étude réalise une évaluation de l'impact écologique des activités humaines sur les habitats et les espèces d'importance communautaire dans le Parc National "Portes de Fer". Une des conséquences majeurs de ces activités que nous avons analyse est la fragmentation de paysages, quantifie en utilisant les métriques paysagères. Les donnes obtenues montrent une baisse des valeurs pour trois indicateurs (MPS, ED, SDI) et une hausse des valeurs pour deux (NumP et IJI). Entre 1990-2006, la fragmentation du paysage a légèrement augmenté, entent que la diversité du paysage a diminué. Les formes de pression humaine sur les habitats ont été groupées en trois catégories: densification résidentielle et des voies de circulation, utilisation du terrain et activités industrielles.

REZUMAT: Analiza fragmentării peisajului și clasificarea ameninţărilor pentru habitatele de interes comunitar în Parcul Natural „Porţile de Fier".

Studiul își propune să evalueze impactul ecologic indus de fragmentarea peisajelor asupra habitatelor și speciilor de importanţă comunitară din Parcul Natural „Porţile de Fier". Fragmentarea peisajului a fost cuantificată utilizând analiza metricilor peisajului. Rezultatele evidenţiază scăderi ale valorilor în cazul a trei metrici (MPS, ED, SDI) și creșteri pentru doi metrici (NumP și IJI). La nivelul arealului s-a înregistrat o creștere nesemnificativă a fragmentării peisajului, coroborată cu o ușoară diminuare a diversităţii peisajului în intervalul 1990-2006. Formele de presiune umană au fost grupate în trei categorii: diversificarea și creșterea densităţii construcţiilor și a căilor de transport, modul de utilizare a terenurilor și activităţile industriale.

INTRODUCTION

The establishment of the European network of protected areas – Natura 2000 – was an important step towards biodiversity conservation at European level (Evans, 2012; Primack et al., 2008). The network was established based on the legal provision of the core Directives of nature conservation: Habitats and Birds Directive (Pullin et al., 2009). The Directives have in their annexes a detailed list of European habitats that present a community interest, mainly due to their ecological characteristics.

A wide variety of studies focus on the habitats of community interest as part of the Natura 2000 network, but only a small proportion approach the social and political implications determining a reduced correspondence between the ecologic and social domains (Popescu et al., 2014). Ecological studies are more frequent, a furthermore proof of the fact that the enforcement of the Habitats and Birds Directives are focused on the conservation of habitats of community interest (Evans, 2012; Popescu et al., 2014).

Research on the conservation of biological diversity revealed that the main threats affecting protected areas networks are the degradation and destruction of habitats, overexploitation, invasive species, pollution or the inadequate spatial planning of the network (Ioja et al., 2010; Primack et al., 2008).

The human impact inside protected areas is amplified by changes in the land use, environmental degradation, the expansion of constructed surfaces and transportation infrastructures, the main effects being represented by the destruction and fragmentation of habitats (Fischer et al., 2007).

Current environmental threats induced by the new consumption models of population – densification of settlements, human induced landscapes and the diversification of economic activities (Antrop, 2004) should be evaluated as synergic process at local or global level (Chincea et al., 2014).

The social and economic vulnerability determined by the amplification of the human pressures imposes a system of sustainable management and territorial planning that consider the new environmental modifications, landscape characteristics and the need for resource consumption (Ioja, 2013; Lindenmayer et al., 2006).

The new directions of analysis should approach conflicts between conservation and development objectives at local, regional and global level (inside the protected areas from Natura 2000 network) (Popescu et al., 2014), with emphasis on the conflicts between agricultural practices and habitats (Pe'er et al., 2014) or the densification of built-up surfaces and the conservation of habitats and species of community interest.

Evaluations of the status of species and habitats inside a protected area can be realized using landscape metrics as an indicator of their dynamic under the influence of anthropic factors (dynamic of the fragmentation degree and landscape structure) (Niculae and Pătroescu, 2011; McGarigal and Marks, 1994; Turner and Meyer, 1994; McGarigal et al., 2002; Pătru-Stupariu et al., 2011; Turner et al., 2001).

Landscape ecology represents a new direction in landscape research that focuses on the structure, composition, functions and the role of human communities in creating and modifying the landscape pattern (Farina, 1998; Forman, 1997; Burel and Baudry, 1999; Forman and Godron, 1986).

In time, the intervention of human factors in the "Iron Gates" Natural Park manifested at different spatial scales and magnitudes, but had a significant role in the spatial and territorial dynamic of habitats of community interest. Species and habitats are differently affected by landscape fragmentation. In the study area among the factors found in the literature are the densifications of built-up surfaces, transportation infrastructures, landscape modification, etc.

The study assessed the ecological impacts induced on the habitats of community interest from the "Iron Gates" Natural Park by anthropic threats and subsequent landscape fragmentation. The research objectives are: a) to quantify landscape fragmentation for the 1990-2006 period using landscape metrics and evaluate its effects on habitats of community interest and b) to identify and classify the main categories of threats and prioritize the areas where they generate environmental conflicts in relation to habitats of community importance.

MATERIAL AND METHODS
Study area
The "Iron Gates" Natural Park is situated in the south-western part of Romania, on the border with Serbia, overlapping the territory of the Mehedinţi and Caraş-Severin counties (Pătroescu and Rozylowicz, 2000; Cucu et al., 2013a, b) and including 20 territorial administrative units. This park was established through Law 5/2000, Section III – Protected areas (Guvernul României, 2013) and is now included in the V category IUCN, managed especially for the conservation of terrestrial landscapes and recreation (IUCN, 2014).

Vegetation includes vascular plants with 1,749 species, 120 subspecies, 570 genus and 131 families (50% of the number of species in Romania) (Matacă, 2005).

The "Iron Gates" Natural Park includes 18 reserves of avifauna, botanical, paleontological, forestry or mixed interest, established under legal provisions and presented in the management plan of the protected area: Balta Nera – Dunăre, Baziaş, Insula Calinovăţ, Râpa cu lăstuni, Divic-Pojejena, Valea Mare, Peştera cu apă din Valea Polevii, Ostrovul Moldova Veche, Locul fosilifer Sviniţa, Cazanele Mari and Cazanele Mici, Bahna, Dealul Duhovna, Gura Văii-Vârciorova, Faţa Virului, Cracul Crucii, Dealul Vărănic, Valea Oglănicului, Cracul Găioara (Guvernul României, 2013; Pătroescu et al., 2004).

The "Iron Gates" Natural Park includes two Special Protection Areas, components of the Natura 2000 network: ROSPA0026 Cursul Dunării-Baziaş-Porţile de Fier and ROSPA0080 Munţii Almăjului-Locvei (Guvernul României, 2011). In 2007 the entire surface of the Park was designated as a Site of Community Importance (ROSCI0206 Porţile de Fier), included in the Natura 2000 network (Ministerul Mediului şi Pădurilor, 2011) (Fig. 1).

In the Site of Community Importance ROSCI0206 "Porţile de Fier"/"Iron Gates" 29 habitats of community interest have been identified according to Annex I of the Habitats Directive (Directiva 92/43/CEE), their conservation requiring the designation of special areas. From the 29 identified habitats (Tab. 1), seven are priority habitats for conservation (Ministerul Mediului şi Pădurilor, 2011).

In addition, a large number of species of community interest form Annex II of the Habitats Directive have been identified in the "Iron Gates" Natural Park, including 15 mammal species (of which one priority species – *Canis lupus*), four species of amphibians and reptiles, 12 fish species, 16 invertebrate species (of which two priority species, *Osmoderma eremita* and *Rosalia alpina*) and 12 species of plants (Ministerul Mediului şi Pădurilor, 2011). The two Special Protection Areas include species from Annex I of the Birds Directive: ROSPA0026 Cursul Dunării-Baziaş-Porţile de Fier – 13 species and ROSPA0080 Munţii Almăj – 21 species (Guvernul României, 2011).

Table 1: Habitats of community interest in the "Iron Gates" Natural Park; *priority habitat types.

3130	Oligotrophic to mesotrophic standing waters with vegetation of the Littorelletea uniflorae and/or of the Isoëto-Nanojuncetea
3140	Hard oligo-mesotrophic waters with benthic vegetation of Chara ssp.
3150	Natural eutrophic lakes with Magnopotamion or Hydrocharition – type vegetation
3260	Water courses of plain to montane levels with the Ranunculion fluitantis and Callitricho-Batrachion vegetation
3280	Constantly flowing Mediterranean rivers with Paspalo-Agrostidion species and hanging curtains of Salix and Populus alba
40A0*	Subcontinental peri-Pannonic scrub
6110*	Rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi
6190	Rupicolous pannonic grasslands (Stipo-Festucetalia pallentis)
6210*	Semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) (* important orchid sites)
6260*	Pannonic sand steppes
6430	Hydrophilous tall herb fringe communities of plains and of the montane to alpine
8120	Calcareous and calcshist screes of the montane to alpine levels (Thlaspietea rotundifolii)
8210	Calcareous rocky slopes with chasmophytic vegetation
8220	Siliceous rocky slopes with chasmophytic vegetation
8230	Siliceous rock with pioneer vegetation of the Sedo-Scleranthion or of the Sedo albi-Veronicion dillenii
8310	Caves not open to the public
9110	Luzulo-Fagetum beech forests
9130	Asperulo-Fagetum beech forests
9150	Medio-European limestone beech forests of the Cephalanthero-Fagion
9170	Galio-Carpinetum oak-hornbeam forests
9180*	Tilio-Acerion forests of slopes, screes and ravines
91AA*	Eastern white oak woods
91E0*	Alluvial forests with Alnus glutinosa and Fraxinus excelsior (Alno padion, Alnion incanae, Salicion albae)
91K0	Illyrian Fagus sylvatica forests (Aremonio-Fagion)
91L0	Illyrian oak-hornbeam forests (Erythronio-Carpinion)
91M0	Pannonian-Balkanic turkey oak – sessile oak forests
91Y0	Dacian oak and hornbeam forests
92A0	Salix alba and Populus alba galleries
9530*	(Sub-) Mediterranean pine forests with endemic black pines

Landscape fragmentation

For quantifying and analysing landscape fragmentation we used the spatial database established by the EEA in the CORINE Land Cover Project for the years 1990 and 2006 (Bossard et al., 2000; Feranec et al., 2010; Heymann et al., 1994), in a grid format with a resolution of 100*100 meters, which we projected in the Stereo 1970 system.
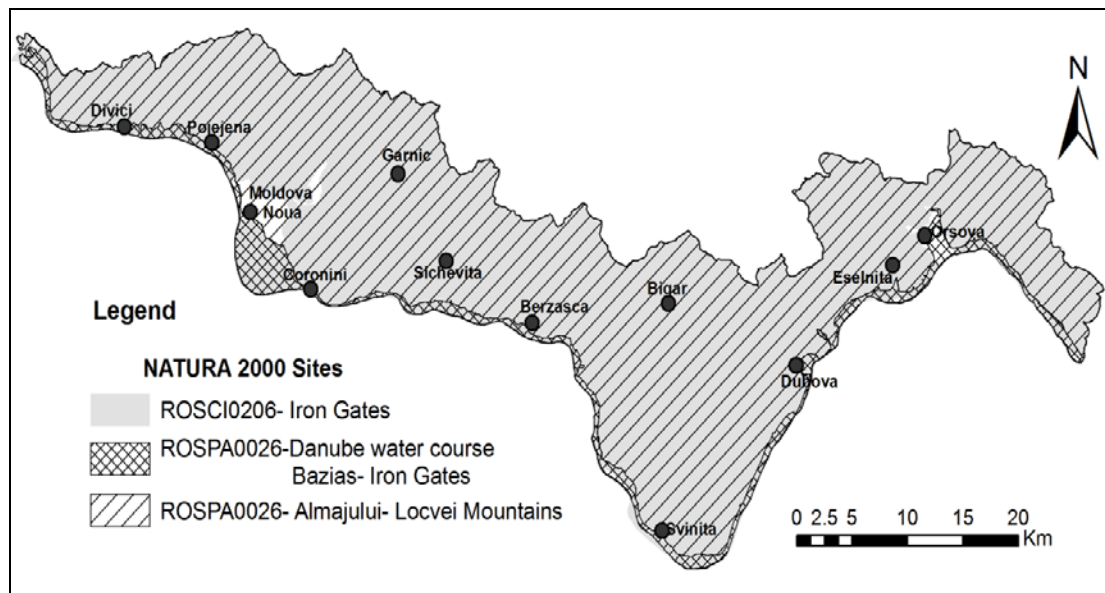
Figure 1: Natura 2000 sites in the "Iron Gates" Natural Park.

The interval corresponds to the Romanian post-communist period characterized by a transition economy. We aggregated land use and land cover classes extracted from the CORINE database (19 classes) in nine main classes (Tab. 2) according to the CLC nomenclature system level II (Eiden et al., 2000) accounting for the particularities of the protected area and the objectives of our study.

Regarding the evaluation of the landscape pattern and the fragmentation of habitats we used five landscape metrics (Eiden et al., 2000; Niculae, 2012), based on the number, size, diversity and the overlap of units in the landscape pattern (Tab. 3).

We calculated landscape metrics using the software Patch Analyst 5.0 (Rempel et al., 2012) and its function Spatial Statistics, developed by the Centre for Northern Forest Ecosystem Research, Lakehead University, Ontario.

Threats analysis

The identification and classification of anthropic threats upon habitats of community interests, and the prioritization of areas with environmental conflicts was done based on the observations and field collection of data, as well as interviews with local actors from the protected area (Cucu et al., 2013a; Primack et al., 2008).

In addition, we consulted a large body of literature (articles, proceedings, reports, management plans) on the topic of environmental conflicts determined by human activities on habitats and species. We validated the data with information from aerial images and cartographic materials.

For prioritizing threats, we used diverse criteria such as the number of landscape components influenced by human activities, environmental impact assessment for different land uses and the proximity to habitats of community interest. Land uses have a spatial and temporal evolution determined by the local and regional development, densification of built-up surfaces and the need to increase the accessibility of the protected area (CCMESI, 2014).

The identification and prioritization of areas with environmental conflicts was realized according to the relation between the densification of built-up and industrial surfaces and habitats of community interest from the "Iron Gates" Natural Park.

Table 2: Classes obtained from reclassification.

Name of CLC classes (level 2)	CLC Code level 2 (level 3)	Name of reclassified classes	Code
Built-up surfaces	11 (112)	Artificial surfaces	1
Industrial and commercial units	12 (121; 123)		
Mines, dumps and sites for construction materials	13 (131; 132)		
Agricultural fields	21 (211)	Arable lands	2
Permanent crops	22 (221; 222)	Permanent crops	3
Pastures	23 (231)	Pastures	4
Heterogeneous agricultural fields	2.4 (242; 243)	Heterogeneous agricultural fields	5
Forests	31 (311; 313)	Forests	6
Shrubs and/or grass vegetation	32 (321; 324)	Natural vegetation	7
Reduced or no vegetation	33 (332; 333)	Unproductive lands	8
Water bodies	51 (511; 512)	Water bodies	9

Table 3: Landscape metrics used in the analysis (McGarigal and Marks, 1994).

Indicator	Formula*/Description	Measure/ Values
Number of patches (NumP)	$NP = n$ The value is 1 when the entire landscape has a single patch. n = total number of landscape patches, without background units	NumP ≥ 1, no limits
Mean patch size (MPS)	$$MPS = \frac{A}{N}\left(\frac{1}{10,000}\right)$$ Values range by the limits of the resolution, scales and the minimum size of the unit. Final value can be divided by 10,000 to convert in ha. A = total landscape surface (m²); N = total number of patches	ha MPS > 0, no limits
Edge density (ED)	$$ED = \frac{E}{A}(10,000)$$ Sum of lengths for all edge segments in the landscape in relation to the total surface. Final value can be divided by 10,000 to convert in ha. E = total lenght (m) of edge segments; can include the landscape limit; A = total surface of the landscape (m²)	m/ha ED ≥ 0, no limits

Table 3 (continued): Landscape metrics used in the analysis.

Indicator	Formula*/Description	Measure/ Values
Shannon diversity index (SHDI)	$$SHDI = -\sum_{i=1}^{m} \left(Pi \circ \ln Pi \right)$$ The value equals 0 when the landscape contains a single unit (no diversity) and increases with the number of classes and/or the balanced distribution between surfaces. The value is equal to minus the sum of the proportional abundance for each type of patch and their proportion. M = number of patches for the i class with close neighbours; i = 1,…, m, types of landscape classes; p_i = perimeter (m) of unit i	$SHDI \geq 0$
Interspersion and juxtaposition index (IJI)	$$IJI = \frac{-\sum_{i=1}^{m'} \sum_{k=i+1}^{m'} \left[\left(\frac{e_{ik}}{E} \right) \bullet \ln\left(\frac{e_{ik}}{E} \right) \right]}{\ln\left(1/2 \left[m'(m'-1) \right] \right)}$$ The index equals 0 when the distribution of adjacent classes between unique classes increases unbalance and equals 100 when all classes are equally adjacent to the other classes. m' = number of class types present in the landscape without the limit; i = 1, …, m, class types; k = 1, …, m, landscape class types; e_{ik} = total length (m) of landscape edges between i and k units; E = total length (m) of landscape edges (including landscape limit)	% $0 < IJI \leq 100$

RESULTS AND DISCUSSION

The analysis of **landscape fragmentation and landscape pattern** revealed decreases for three landscape metrics (MPS, ED, SDI) and increases for the other two (NumP and IJI) (Tab. 4). The number of patches (NumP) recorded insignificant increases, with approximately 1.8% for the analysed timeframe, from 428 units in 1990 to 436 units in 2006. The values demonstrate a small increase in landscape fragmentation. Edge density (ED) decreased with 1.24%, reaching a value of 20.67 in 2006, while the mean patch size (MPS) decreased with 1.84%, arguments for landscape fragmentation and an increased complexity of shapes.

Table 4: Landscape metrics values for 1990 and 2006; *NumP-Number of patches; ED – Edge density; MPS – Mean patch size; SHDI – Shannon diversity index; IJI − Interspersion and juxtaposition index.

	NUMP*	ED	MPS	SHDI	IJI
1990	428.00	20.93	299.53	1.24	63.19
2006	436.00	20.67	294.03	1.23	65.33

The Shannon Diversity Index (SDI) presents a small decrease of 0.81%, from 1.24 to 1.23 in 2006. The index is used for quantifying landscape diversity (Pătru-Stupariu et al., 2009; Pătru-Stupariu et al., 2011; Schreiber et al., 2003) based on the composition (number of classes) and structure (distributions and proportions covered in the landscape) (Eiden et al., 2000; Niculae, 2012; Schreiber et al., 2003).

The value of the index increases as the number of land use classes amplifies and their distribution in the landscape balances (Schreiber et al., 2003). In the case of the "Iron Gates" Natural Park, the insignificant decreases in the Shannon Diversity Index (from 1.24 to 1.23) would imply a reduced diversity of the landscape. However, since the number of classes remained constant for the analysed timeframe this reduction can be justified by a decrease in the proportion of several land uses and covers.

Values of the Interspersion and Juxtaposition Index (IJI) increased by approximately 3.4% in 2006 compared to 1990 (2.14 units). The high values for both years indicated an increased adjacency between landscape units from the same class in relation to the others, their distribution becoming regular in a progressive manner.

The five landscape metrics we analyzed for the years 1990 and 2006 reveal an insignificant increase of landscape fragmentation and a reduced decrease of landscape diversity. One of the reasons that generated these results was the establishment of the protected area status in 2005; land use and land cover changes recording a low manifestation in the protected area. Landscape fragmentation was determined also by the densification of built-up surfaces in settlements from the "Iron Gates" Natural Park.

Works on the European road E70 lead to the fragmentation of forest landscapes, affecting the structure of habitats consisting of calcareous and siliceous rocky slopes with chasmophytic vegetation. Constructions along the Danube banks (Fig. 2) destructed the habitats of alluvial forests with *Alnus glutinosa* and *Fraxinus excelsior*.

An important habitat for orchids, semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia) was affected by the fragmentation for obtaining agricultural lands in the proximity of settlements as Berzasca or Dubova.

Figure 2: Constructions along the Danube banks at Dubova.

Based on field researches and literature reviews we identified and classified a series of anthropic **threats** to landscapes in the "Iron Gates" Natural Park, with major negative effects on the habitats of community interest.

We also prioritized the areas in which a series of **environmental conflicts** can be found.

Human activities that determine pressure on the habitats of community interest belong to three categories: densification of human settlements (the number and density of permanent and temporary settlements, their shape and size), densification of transportation infrastructure (at national, county and local level) and land-uses (agricultural lands, animal growth, forestry, industrial activities) (CCMESI, 1999; CCMESI, 2014; Niculae, 2012). We prioritized the following human activities that influence habitats of community interest (CCMESI, 2014):

– Densification of built-up and commercial surfaces. The main threat is represented by the construction of vacation housings along the Danube, with direct effects on the ripicol and riparian habitats, as well as protected species (such as *Testudo hermanni*). The new insertions represent direct threats through the destruction of habitats (CCMESI, 2014);

– Transport activities on the roads and the Danube, especially along the E70 affecting habitats (Fig. 3) with rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi;

– Intensification of agricultural activities, especially in the area of depression basins or mountainous plateaus, affecting habitats with rupicolous calcareous or basophilic grasslands of the Alysso-Sedion albi or the semi-natural dry grasslands and scrubland facies on calcareous substrates (Festuco-Brometalia);

– Mining and energy production (at Cozla, Eibenthal, Baia Nouă) with direct impact especially on forest landscapes (Fig. 4). A threat is represented by the tailing dumps situated in the proximity of habitats. The existence of the "Iron Gates" hydro energy system has effects on the habitats, mainly through water level oscillation. Lately numerous wind turbines have been builded in the study area with direct effects especially on bird species and their habitats.

Settlements have an unbalanced distribution in the "Iron Gates" Natural Park, with higher densities along river valleys and the main roads, and in areas where slopes and fragmentation are reduced. Relief factors of restrictiveness determined a reduced density of population in the Caraş-Severin and Mehedinţi counties.

A large proportion of the constructed surfaces and industrial activities are located in the proximity of protected areas and habitats of community interest (Fig. 5) increasing the probability of environmental conflicts emerging.

Numerous conflict areas from the "Iron Gates" Natural Park are concentrated around industry, many of them being residual activities from the communist period. The exploitation of different resources determined a high impact on environment, respectively on habitats and species of community interest. Conflict areas can be found around exploitation quarries, tailing dumps, mines or abandoned constructions (Moldova Noua, Cozla, Baia Nouă, etc.).

The city of Moldova Nouă is confronted with the largest number of conflict areas due to industrial activities (Chincea et al., 2014). The main conflict area induced by industrial activities is located at the tailing dump of Moldova Nouă, situated near the Ostrovul Moldova Veche wetland (Fig. 6) – part of ROSPA0026 Cursul Dunării – Baziaş-Porţile de Fier. It has a surface of about 270 ha and represents a cross-border environmental degradation sources.

These environmental conflicts are generated by the densification of built-up surfaces in the adjacent settlements and agricultural land uses. Such areas are found around the settlements of Eşelniţa, Dubova, and Berzasca, in which the construction of vacation residences and their endowments determined the emergence of new environmental conflicts.

Figure 3: Landscape fragmentation by E70.

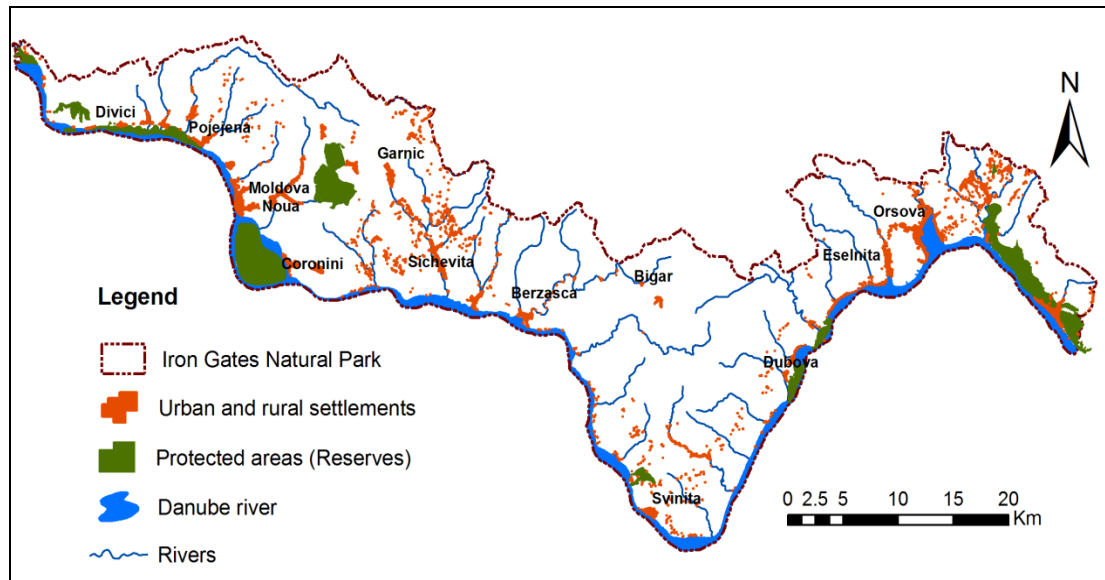Figure 4: Mining exploitation in the proximity of Ciucarul Mare.

Figure 5: Densification of built-up surfaces in relation with reserves in the "Iron Gates" Park.
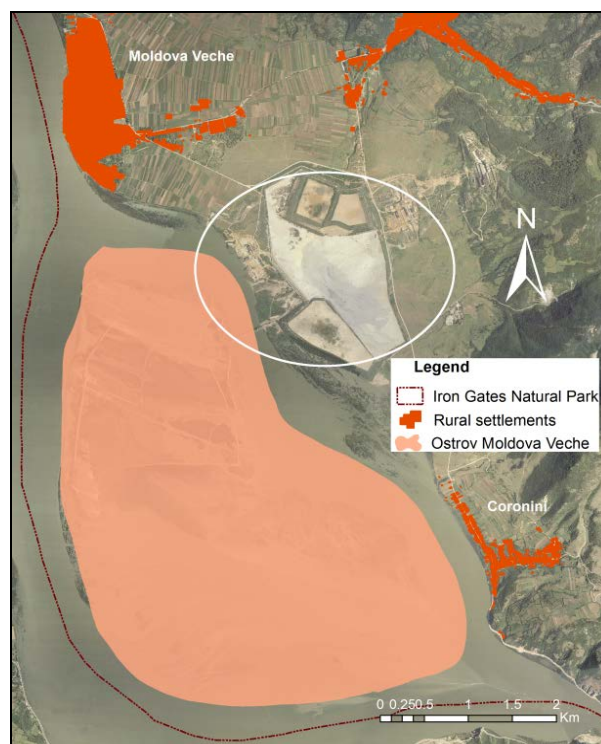

Figure 6: Conflict area determined by the presence of the tailing dump in the proximity of the Ostrovul Moldova Veche wetland.

Another area in which environmental conflicts are manifesting is represented by the area of the Calinovăț Island and the Divici – Pojejena wetlands (Figs. 7 and 8).
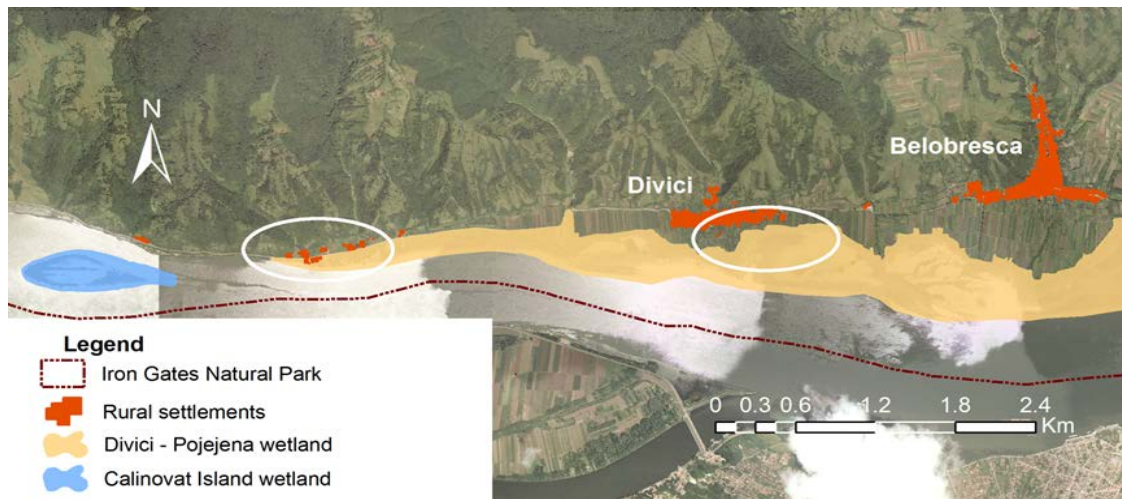
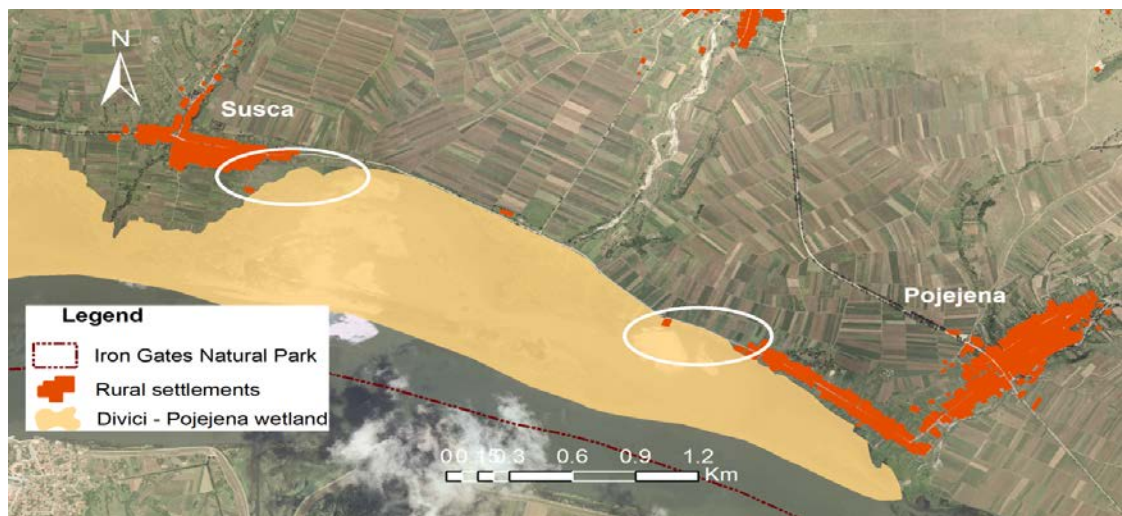Figure 7: Conflicts generated by the densification of built-up surfaces.

Figure 8: Densification of built-up surfaces and intensification of agriculture.

CONCLUSIONS

The "Iron Gates" Natural Park represents an area in which landscapes have suffered reduced modifications after its establishment as a protected area (2000) in comparison with territories in the proximity that lack a conservation status (CCMESI, 2014). The ecological integrity of the environment in the "Iron Gates" Natural Park was in a low proportion influenced by landscape fragmentation.

Recent changes in the structure of landscapes have not yet induced significant changes in spatial relations established in time between landscape elements. The connectivity and permeability of habitats is of significant importance in the framework of a protected area where the development of human activities (transportation, energy, agriculture) tends to determine fragmentation and represent barriers in the dispersion of species.

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