ASSESSMENT OF THE INFLUENCE OF ANTHROPOGENIC FACTORS ON ELEMENTS OF THE ECOLOGICAL NETWORK IN VOJVODINA (SERBIA) USING THE LEOPOLD MATRIX

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Abstract: Salt steppes and marshes represent the most valuable ecosystems in the world, providing numerous ecosystem services that are extremely vulnerable to anthropogenic influences. These types of habitat in the territory of Serbia are most dominant in Banat and a significant portion of them is under protection or in the process of becoming protected. The section surrounding the protected areas of Slano Kopovo Special Nature Reserve, Rusanda Nature Park and Okanj Bara Special Nature Reserve with the non-building area of Novi Bečej, Kumane, Melenci, Elemir and Taraš cadastral municipalities, has been chosen for the analysis. The aim of this paper was to assess the influence of specific anthropogenic factors on the elements of an ecological network using the analytical method that can generate the required results in a manner suitable for presentation to various stakeholders. To achieve this aim, the Leopold matrix model, used for assessing anthropogenic influence on the environment, has been chosen. The specificity of this issue of protecting and preserving elements of an ecological network resulted in the need to isolate and evaluate the factors affecting the preservation of habitats and functionality of ecosystems, unlike the concept of Leopold matrix, which treats all factors as equally important in the process of evaluation. Evaluation results indicate significant effects of historical, perennial manner of using the area and other resources in the non-building area.

Key words: Banat; protected areas; Pannonian salt steppes and salt marshes; endangering factors; Leopold matrix

Received: March 3, 2015; Revised: March 19, 2015; Accepted: April 2, 2015

INTRODUCTION

The preservation of biodiversity and protection of ecosystems is a prerequisite for maintaining the functionality of the biosphere and its structural elements (Kicošev and Sabadoš, 2007). The loss of any element or disruption of natural processes have irreparable consequences for the functionality of ecosystems and lead to the decline in biodiversity (Kicošev and Sabadoš, 2008), affecting the flexibility and overall resilience of ecosystems (Balmford et al, 2008). One of significant causes of changes in ecosystems are changes in the purpose or the manner of land use (EEA, 2010), when the impact on ecosystems is made by conversion, degradation and the change in spatial connection (Leibowitz et al., 2000), resulting in fragmentation (Kristensen, 2003), water regime changes (Athanas et al., 2006), climatic conditions’ deterioration (Armstrong-Brown et al., 1995), soil erosion (Evans, 1996) and compression (Schrader and Lingnau, 1997), the spreading of dangerous substances through ecosystems, and the increase in nutrient content (eutrophication) (Butchart et al, 2005). The edge effects may affect an area of several hundred meters (Zhu et al., 2002; Beckerman et al., 2008), which, along with
the cumulative ecological effects related to the different ways of land use (Godefroid and Koedam, 2004), causes changes in the composition and structure of ecological communities (Forman and Deblinger, 2000), and in vulnerable habitat types, resulting in the destruction of portions of habitats (Coffin, 2007). In regions such as Vojvodina, with significantly altered natural features (EEA, 2002), a great pressure is put on the functionality of ecosystems, and their resistance to other influences is reduced (EEA, 2012).

According to the data from the Regional Spatial Plan of the Autonomous Province of Vojvodina, about 76% of the territory is covered by arable agricultural land and the share of building area is about 12%, revealing intensive land use (Sabadoš, 2009), continuing from the previous period (Marinić, 1997). The natural vegetation of the steppe and forest areas is almost entirely destroyed and once vast wetlands have been reduced (Sabadoš, 2009), mostly by drainage, channeling of rivers, and the building of embankments and dams (Bošnjak, 2011). Intensive arable farming and a reduction in mixed livestock and arable farms have led to a uniform landscape (Nassauer and Westmacott, 1987) and the disappearance or great vulnerability of the remaining wild relatives of farm animals (Rischkowsky et al., 2007), thus contributing to the decline in biodiversity (Meeus, 1993). The protection of the remaining entieties that are more or less eligible for (i) the preservation of rare and endangered organisms, (ii) sustainability of biodiversity and (iii) performance of ecosystem services is realized by the establishment of an ecological network of protected areas. The inclusion of elements of the ecological network in sustainable development involves the use of ecosystem services in accordance with the capacity of the area while maintaining the functionality of ecosystems and the quality of the environment. In order to resolve this issue, it is necessary to evaluate the effects of construction and activities (Kicošev et al., 2014b), and to have the knowledge of the vulnerability of ecosystems to different influences from the surroundings (Kicošev et al., 2014a). The successful implementation of the given activities depends on the active cooperation of local users and other stakeholders (Kicošev et al., 2011). A clear presentation of the key impacts and accompanying changes in ecosystems in a manner comprehensible to all participants may be helpful in the decision-making process. The aim of this paper was to assess the influence of certain anthropogenic factors on elements of the ecological network in order to decide on the most important activities for obtaining a satisfactory quality of the environment and ecosystem functionality. The possibility of using an analytical model, which may both be effective in achieving the goal and easy to process in order to present the data, is presented in this paper.

MATERIALS AND METHODS

The remaining fragments of natural habitats in the territory of Vojvodina are included in the protected areas and represent a part of the national ecological network. Pannonian types of salt habitats (Pannonian salt steppes and salt marshes) represent significant elements of the national ecological network.

Features of the analyzed types of habitat

Salt steppes and marshes are among the most valuable ecosystems in the world, providing numerous ecosystem services, but their habitats are highly vulnerable to anthropogenic influences (Gedan et al., 2009). Wetlands contribute to the regulation of microclimate conditions (Bullock and Acreman, 2003) and they have the capacity to remove toxic substances, heavy metals and excessive organic matter from water and sediments (Simpson et al., 1983). Numerous research studies (for example, Rudolph and Dickson, 1990; Bodie, 2001) confirmed the presence of great biodiversity in the habitats bordering wetlands. Natural habitats near crops significantly influence the abundance of species of pollinators (Steffan-Dewenter, 2003), their number (Heard et al., 2007) and the composition of communities, with the survival of pollinator communities depending on the size of the fragments (Steffan-Dewenter et al., 2002). Saline habitats that have been used for pasture for centuries represent significant reservoirs and sinks of greenhouse gases, since the carbon dioxide absorbed by
the vegetation binds to the soil substrate (EA, 2007 in: DEFRA, 2009). The landscape and vegetation features of these habitats are the result of a specific water regime and extreme living conditions (semi-arid climate, increased content of mineral salts, rotation of wet and dry periods) in which saline habitat vegetation survives (Dajić, 1996).

The Pannonian salt steppes and salt marshes (EUNIS Habitat Classification: Е6.21), once one of the dominant types of primeval vegetation of Vojvodina, were valued (under code: 1530) as priority habitats for protection in the neighboring countries of the European Union (Directive on Habitats - Directive 92/43/EEC Annex I). These habitat types are most dominant in Banat, and a significant part of them is under protection or undergoing the protection procedure. The territory of central Banat in the surroundings of the protected areas of Slano Kopovo Special Nature Reserve (SNR), Rusanda Nature Park (NP) and Okanj Bara Special Nature Reserve (SNR) covering the non-building area of Novi Bečej, Kumane, Melenci, Elemir and Taraš cadastral municipalities has been selected for the analysis (Fig. 1).

Description of the manner of utilization of the area surrounding the habitats

Ever since the Neolithic period and the emergence of first dwellings in this area (Marinković, 2010) up until today, the impact on the environment has been intensifying, resulting in temporary or permanent consequences for the natural values of this area. Due to the large wetland areas (Fig. 1) and frequent wars in this territory, until the 18th century Banat was sparsely populated area and regarded as neglected in the agrarian sense. Farming intensified in the 18th century during the systematic colonization of Banat (Grošin, 2009) and greater effects on natural habitats are linked to the period up to the beginning of the 19th century, when significant changes in the landscape features of the analyzed area occurred after the regulation of the Tisza and extensive drainage which followed (Cerović, 1984), and following changes in the purpose of the marsh land (mostly its conversion into arable land), pressure on the saline habitats (ploughing, afforestation) and expansion of the building area, road network and so on.. The late 19th and beginning of the 20th century have been characterized by the emergence of different influences on the functionality of ecosystems, such as the expansion of industrial complexes and infrastructure (Petrović, 2010), with increased exploitation of resources and emission of pollutants into the environment. Intensive land use for agricultural production was enabled by the first heavy machinery for land tillage and fertilizers (Grubić, 2010). The agrarian reforms after the wars were followed by a series of futile attempts at “purposeful utilization” of the salty soil (Cerović, 1984) and the use of pesticides was another contribution to the continuation of intensive crop production. Crop production was followed by intensive livestock farming in settlements, starting from 1959 in Melenci. Intensive fish farming was started in 1965, after turning the salinized lake “Ostrovo” (a segment of paleomeander between Slano Kopovo and Rusanda) into a eutrophic freshwater body. The remaining three salinized lakes that compose protected areas preserved some of their original features owing to the mainly traditional use of the area by the local population, as well as the sustainable use of the healing peloid, used since the 1600s (Cerović, 1984) to date (Kicošev, 2012).

Constant pressure on elements of an ecological network by heterogeneous socio-economic factors (mostly ending in numerous conflicting aims regard-
ing the use of the area) require the application of certain models in decision making about the possibilities of sustainable development and priority activities for preserving the functionality of ecosystems and the quality of ecosystem services. According to the data obtained after the field research, it is possible to assess the overall effects on ecosystems. However, it is difficult to quantify the amount of negative impacts on habitats, animal and plant populations, since the ecological effects of full-scale change in a landscape become evident only after several decades (EEA, 2011).

Use of the Leopold Matrix in decision-making

The choice of a decision-making model faces the challenge of adequate presentation of dynamic, spatial, distributive and non-linear natural processes (Hwang and Masud, 1979), with numerous complex questions for which decision-makers cannot provide precise and comprehensive answers. In the situation where a holistic approach is required, it is advisable to use the simplest available model that can generate the requested result. A simple model has the advantage of providing a simple explanation of its results (Kubiak et al., 2008).

In order to resolve the issue of anthropogenic influences on the central Banat ecological network area, an a-priori decision-making concept was used, based on the prior evaluation of criteria according to which decisions are made (Deb, 2010). The choice of operational approach is based on the application of a simple, empirical model with graphic representation of data in a table. The basic structure of a table is formed according to the model of the Leopold matrix (Leopold et al., 1971), which is to support the decision-making process during the drafting of environment assessment studies (Puczkó and Rátz; Josimovic et al., 2014), while treating all elements in the landscape as equally important in the evaluation procedure. The specificity of the problem of protecting and preserving elements of the ecological network resulted in the need for isolation and special evaluation of those elements that affect the preservation of habitats and functionality of ecosystems. Identification of these factors was carried out by considering the dominant ways of land use in building and non-building areas and key activities that in time have influenced the change of habitat conditions, content and transfer of pollutants and the status of species. Changes in habitat conditions most significantly causing the loss of saline habitats include fragmentation, change in soil composition and structure, changes in water regime and microclimate factors. The content and transfer of different types of pollutants in the environment was emphasized as a separate type of impact on habitats according to their behavior in the biosphere and the character of the effect on the wildlife.

Assessment of the impact of endangering factors

An assessment of the impact of endangering factors was conducted by evaluating intensity and duration. Intensity of impact was classified into five categories (small, lower-medium, higher-medium, significant and great), and impact duration (years) into five levels (0-25, 26-50, 51-75, 76-100). Evaluation of the intensity and duration was carried out by scoring (1-5), and the manner in which the influence exerted its affect was marked by shading the section of the field representing direct (dark) or indirect impact (light). If the effect of a certain impact is considered to be irrelevant, fields do not contain written values (-) and are not shaded. Fields in the table are divided into two sections, one showing the values for impact intensity and the other showing duration of the impact. In impact duration evaluation, an increase in the value of a point indicated the increase in the time during which the habitat had been exposed to a particular impact. The shortest period was 0-25 years and the longest more than 100 years. In impact intensity evaluation, an increase in the point value indicates the increase in the negative effect resulting from the deterioration of the status of natural landscape features. Gradation of impact (small, lower-medium, higher-medium, significant, great) was carried out by applying approximate values of spatial, qualitative and quantitative change indicators. Consideration of spatial indicators (approximate reduction of the area covered by wetlands and other natural habitats due to the increase in areas
modified by human influences) had a key role in evaluating the fragmentation level, change in water regime and intensity of land use. Consideration of qualitative and quantitative indicators (in terms of types of substances and assumed quantity) is significant for the nutrient-impact evaluation which occurs as eutrophication, impact of heavy metals, hydrocarbons and other dangerous substances, greenhouse gases (GHG) and other substances whose emission from different sources has an impact on global changes in the biosphere. Each of the given factors influences the state of species to a smaller or greater extent.

The results shown in the charts depict the estimated intensity of the impact source and the consequences of impact. The resultants of the total value of the source/consequence of the impact were compared to the reference values for intensity of low (3.33), medium (6.66) or high level (9.99). These values were obtained by applying the following formulas developed for the purpose of this research:

\[
R(y) = \sum (i_y + t_y) \cdot n_y^{-1}(1),
\]

\[
R(p) = \sum (i_p + t_p) \cdot n_p^{-1}(2),
\]

where \(R(y)\) = resultant related to the aggregate value of the impact source; \(R(p)\) = resultant related to the aggregate value of the impact consequences; \(I\) = intensity value of the single impact source (\(y\)) or consequence (\(p\)); \(t\) =duration value of the single impact source (\(y\)) or consequence (\(p\)); \(\Sigma (i+t)_y\) = the sum of all values given within a single row/specific source; \(\Sigma (i+t)_k\) = the sum of all values given within a single column/specific consequence; \(n_y\) = number of fields with evaluated source within a single row; \(n_k\) = number of fields with evaluated consequence within a single column.

**RESULTS**

In Table 1, values for the impact on natural habitats from the non-building area are shown. The high level of impact originates from the manner of land use and...

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**Table 1:** Impacts on natural habitats from the non-building area.

<table>
<thead>
<tr>
<th>Impact from non-building areas</th>
<th>Changes in habitat conditions</th>
<th>Content and transfer of pollutants</th>
<th>Species state</th>
</tr>
</thead>
<tbody>
<tr>
<td>Impact intensity</td>
<td>Fragmentation and loss of habitats</td>
<td>Soil structure and composition changes</td>
<td>Changes caused by erosion</td>
</tr>
<tr>
<td>Monoculture plantings</td>
<td>5</td>
<td>2</td>
<td>4</td>
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<tr>
<td>Intensive land use</td>
<td>4</td>
<td>5</td>
<td>3</td>
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<tr>
<td>Use of mechanization</td>
<td>3</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Flood defence and drainage activities</td>
<td>4</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>Saline habitats ploughing</td>
<td>2</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>Saline habitats afforestation</td>
<td>2</td>
<td>4</td>
<td>4</td>
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<tr>
<td>Use of fertilizers</td>
<td>4</td>
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<td>3</td>
</tr>
<tr>
<td>Use of pesticides</td>
<td>4</td>
<td>2</td>
<td>4</td>
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<tr>
<td>Ploughing of boundaries</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Removal of shrubs and trees</td>
<td>3</td>
<td>2</td>
<td>3</td>
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<tr>
<td>Watercourses vegetation belts removal</td>
<td>5</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>Intensive animal husbandry</td>
<td>3</td>
<td>3</td>
<td>4</td>
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<tr>
<td>Intensive fish farming</td>
<td>4</td>
<td>3</td>
<td>1</td>
</tr>
</tbody>
</table>
management of water regimes, with significant effects on the extent of fragmentation, basic composition and structure of soil, as well as the transfer of pollutants through all spheres of the environment. Also, the diminishing diversity and vegetation coverage occurring as an effect of human activities were registered as a significant cause of change in habitat conditions due to an altered transfer of matter through the environment. Out of the total number of single impacts (117), the share of those recognized to be immediate was 59%, indirect 36%, and only 8% were considered irrelevant. The largest percent of immediate impacts was registered as the result of removal of different natural vegetation types.

The resultants representing aggregate values for the sources of impacts show that activities originating from the non-building section of the area (Fig. 2) have intensive impact on natural habitats and functionality of ecosystems. Of the total number of impact sources (13), 5 (38%) enter the area of high intensity level, 2 (15%) are on the border between medium and high intensity level and none of them is registered as an impact of low intensity level. Such a situation is certainly the result of the long duration period of most of these sources of impact. Moreover, the diffuse character of impact sources, direct focus of activities on natural habitats and vulnerability of ecosystems had a great role in this. Very high values of the influences of drainage, use of machinery, etc. indicate changes in habitat conditions and the content and transfer of pollutants are largely caused by intensive animal husbandry and ploughing of natural vegetation strips and clusters.

The resultants representing aggregate values for the consequences of impacts indicate a significant endangerment of natural habitats and functionality of ecosystems (Fig. 3). All considered consequences enter the scope of medium and high intensity level, the most prominent being the fragmentation/loss of habitats, endangerment/loss of species and eutrophication. In this case, eutrophication was considered a consequence of an increase in the content of nutrients, but it can also be viewed, along with other consequences (e.g. altered water regime, changed composition and structure of soil) as an indirect cause of the loss of oligotrophic halophyte communities.

**DISCUSSION**

The research on the section surrounding the protected areas of Slano Kopovo SNR, Rusanda NP and Okanj Bara SNR indicates that the influences originating from the non-building area are mostly diffuse and related to activities in the areas of agriculture and water management. The greatest values were obtained for activities known to represent significant endangering factors for the preservation of biodiversity and survival of natural habitats (especially saline habitats). The most evident changes in the habitat related to changes in the water regime occurred because of flood defense
and drainage activities. Inclusion of saline habitats into intensive drainage put their basic values under threat. The ploughing of saline habitats in the past, which is also present nowadays, releases enormous amounts of carbon dioxide sequestrating in the soil for centuries. Saline habitat communities that survive in semi-arid climates with low organic-matter-content soils are especially threatened by conventional agriculture methods. The loss of natural habitats and expansion of areas with single crops and inappropriate use of agricultural chemicals result in the decline of the quality of ecosystem services of water purification, dissolution of waste material and transfer of dissolution products through ecosystems, etc.

Years of experience in nature protection have shown that the preservation of habitats and other elements of an ecological network mostly depend on successful cooperation with the local users of land and other stakeholders. Preparatory activities for the negotiation phase in the decision-making process demand an objective and reasonable evaluation of factors significantly affecting the state of the environment, functionality of ecosystems, survival of species and preservation of their habitats’ integrity. Objectivity of evaluation depends on the availability of key data and requires a holistic approach. The intelligibility of the analytical process to the general public and transparency in presenting the evaluation results depend on the choice of model. Using a simple model that can generate the required results and is not complicated in presentation wins a greater confidence and enables better communication with other participants in the decision-making process. However, it is necessary to bear in mind that the quality of analysis of available data in simple models greatly depends on the experience of analysts.

Evaluation results indicate the significant effects of historical, long-standing ways of using the land and other resources in the non-building area. A solution to the problem of pollutant emissions from settlements and separate industrial complexes on the building land can be largely achieved by completing the sewage infrastructure, constructing and maintaining the operation of the system of wastewater treatment and emission of products into the atmosphere, and by implementing adequate solid-waste management, etc. However, a reduction/mitigation of the impact of emissions from diffuse sources (such as agricultural land) requires the use of biological methods for the regeneration of environmental elements and the return to primarily traditional ways of using arable land and pastures, which have a positive role in the preservation of biodiversity and ecosystem functionality.

This paper presents the possibilities of using the Leopold matrix to assess the impact of certain anthropogenic factors generally adversely affecting habitats and species. Application of Leopold matrix tailored to meet the requirements of nature protection is particularly important for more efficient communication with land users, which contributes to the improvement of management of protected areas and other elements of ecological network. This model should be further developed for the evaluation of impacts originating from artificial sources, such as noise, vibrations, light and other impacts to which some species are extremely sensitive.

Authors’ contributions: AB: Analysis of data regarding the impact of agriculture and water management on the environment. BP: Analysis of data regarding the purpose of the area within the ecological network in Vojvodina. IM: Adjustment of the purpose of the Leopold matrix to the specific requirements of the nature protection. JR: Analysis of the geographical factors and human history. VK: Analysis of the needs and possibilities of using models for assessment of influence of anthropogenic factors on elements of ecological network, making of the paper structure, drawing conclusions.

Conflict of interest disclosure: Conflicts of interest have not been identified.

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