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MAPPING ROMANIAN WETLANDS – A GEOGRAPHICAL APPROACH

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ABSTRACT

Romanian wetlands are areas of high importance in terms of providing ecosystem services and a great biodiversity. In this study, the territorial distribution of the wetlands is analyzed based on the high resolution layers (HRL) from the European wetlands database (Copernicus Land Programme), which includes a raster having a resolution of 20m. The analysis performed takes into consideration the climatic features, topography, soil texture, land use type and the biogeographical characteristics of each wetland area in Romania. The results of the analysis show that 96% of the wetlands are located in the plain area, at under 300m elevation a.s.l., in a dry climate (75%), with less than 500 mm/year of precipitation and with an annual average temperature above 10°C (90%). Regarding the soil texture there is a higher variety of distribution, more than 34% being peat soil type and 38% of the wetlands are located in areas with other dominant land use than marsh or wetland. By combining the climatic parameters, temperature and precipitation, the "de Martonne" climatic index for each region of Romania was obtained and used in wetlands type classification, by biogeographical properties. To analyze the geographical signature of each Romanian wetland, the Principal Components Analysis (PCA) method was used in order to highlight geographical features. The most dominant characteristics of the wetlands are the topography and biogeographical properties, through which has been mapped the wetland ecosystem type at a national scale.

Keywords: Wetland, Mapping Ecosystems, Principal Components Analysis, Geographical Analysis, Ecosystem Services, Romania

1 INTRODUCTION

Mapping and assessing the ecosystem services intend to support current needs regarding the understanding of ecosystems' functionality and their contribution to the sustainable development of society. Mapping the ecosystems is part of the Fifth European Directive of Biodiversity which aims to improve the state of the ecosystems by reducing the habitats degradation (EC, 2011), knowing the areal extension and their ecosystem services production. This activity is suitable for stakeholders in the management of ecosystem services.

In Romania, the wetlands always played an important role in the geography and in the economy of the country. The large scale interaction of man with the wetland dates from the XVIII century to the XIX century, when approximately 850.000 ha were drained for agricultural purpose in Western Romania (Romanescu, 2003). The second major action regarding the wetland area planning was developed during the 1960-1989 period, when more than 1.000.000 ha of wetlands from the floodplains of the majors rivers of Romania were embanked with the objective of eliminating the flood risk (Romanian Academy of the S.R., 1969), wetland related diseases, like malaria (Ciuca, 1956) and to obtain new agricultural lands. The Danube Lower floodplain was one of the most important area of land planning with more than 860.000 ha of wetlands transformed in high value agricultural land (Iordan, 2005).

Despite the high environmental impact, these works provided more than 1 mil. ha of arable land in Romania, offering protection against flood risks and eliminated one of the most backward problems of Romania, malaria.

Romania have adopted the Ramsar Convention in 1991 (Law no. 5/1991), and in the international and national scientific communities new debates appear regarding the need of restoration of the wetlands, especially in the Danube Floodplain, which possibly implies a lot of economical and ecological costs, most of them non-feasible under these above mentioned aspects (Bularda and Visinescu, 2014).

Studies that present the state of the Romanian wetlands are presented below:

- The reconstruction of wetlands Pringale et al. (1991);
- Wetland loss impact Muica and Zavoianu (1996), Vadineanu et. al (2003);
- The analysis of extention and the types of wetlands, Torok (1999, 2000);
- Regional or local studies regarding the distribution of wetlands or their functionality Romanescu et al (2011), Vartolomei (2012) and INCDPM (2014, 2015).

The paper is structured in four parts as follows: the first part contain the description of the study area, the second part of the study includes the description of the data and the methods used in the analysis, the third part show the results and discussions and finally the conclusion of the study, which is presented with respect to the reliability of the employed methods.

1.1 Study area

Officially in Romania there are 843.700 ha of wetlands, marshes, lakes and permanent water surfaces, accounting for 3.5% of national surface (INHGA 2013). In this article the study area reffers only to the wetlands detected in the satellite imagery of High Resolution Layers (HRL) from Copernicus Land database, and covers an area of 386.000 ha. The HRL product *Wetlands*, have a spatial resolution of 20 m and includes all wetlands with water depth lower than 0.5 m (Langanke et al., 2015).

By area, the largest wetlands are located alongside the Danube flood plain or in the Danube Delta (INHGA 2013; Torok 2000), meanwhile as incidence the wetlands are evenly distributed alongside the rivers in Romania or in the vicinity of the big lakes, in all geographical regions (Figure 1).

2 DATA AND METHODS

The data used to delineate the wetland ecosystem is obtained from the HRL raster dataset of European wetland (Langanke, 2015). This layer was used to extract the areal extension of Romania's wetlands, with a minimum mapping unit of 20m and water depth less than 0.5 m.
For mapping the wetlands features were necessary the following datasets:

- The terrain model of EU-DEM (ESA, 2013) with a resolution of 20 m, which served for comparison of the morphometric properties of wetlands;
- The temperature and precipitation rasters (Hijmans et al., 2005), used for climatic analysis of the wetlands;
- The land use type from CLC 2012 (Maucha et al., 2014), used to extract the land management type of the wetland (ex.: human made wetland);
- De Martonne Aridity Index (De Martonne, 1926), obtained by the combination of temperature and precipitation rasters (1), with the scope of analyzing the biogeographical features of the wetlands.

$$\mathbf{A = P / T + 10} \qquad (1)$$

Where: **A** – de Martonne Aridity Index; **T** – Average Annual Temperature; **P** – Average Multiannual Precipitations

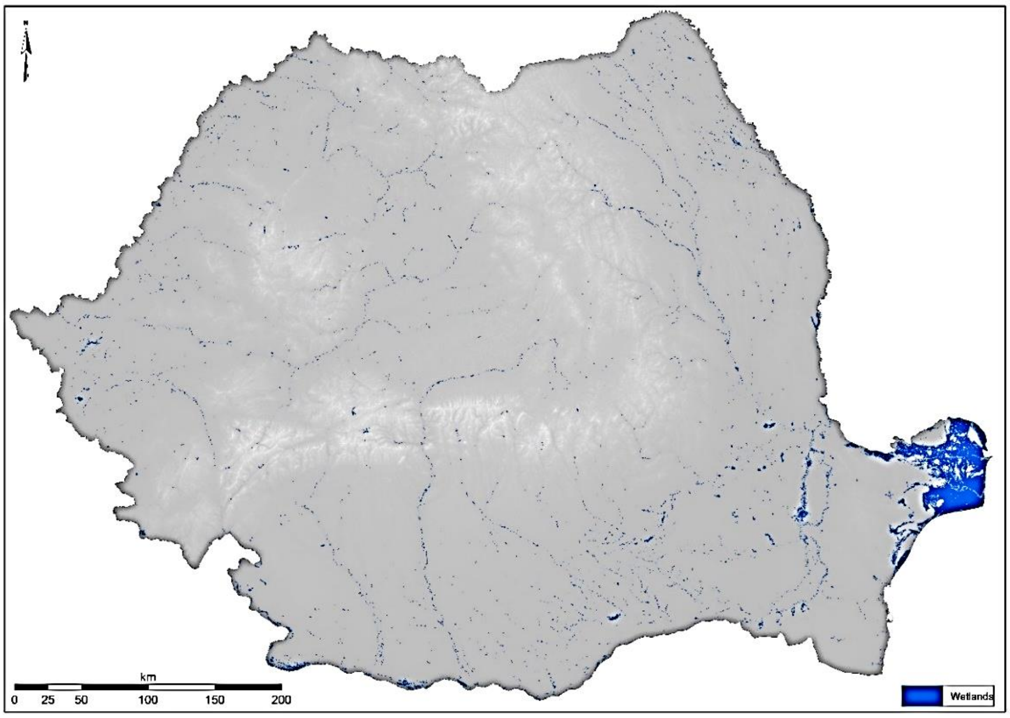

Figure 1. The distribution of Romanian's Wetlands

This study aims to map the Romanian's wetlands, based on two approaches: geographical distribution analysis and Principal Components Analysis.

First method was employed to map the wetlands, and consisted in superimposing thematic layers (Bailey 1983 and 2007, Banko et al. 2013) of different maps type like: soil texture, land use, precipitations, temperature, topography and the climate type with the help of GIS techniques. This method offer a geographical description of the wetlands, resulted by the combination of thematic layers, which could be used as regionalization in function of their physical properties (Figure 2).

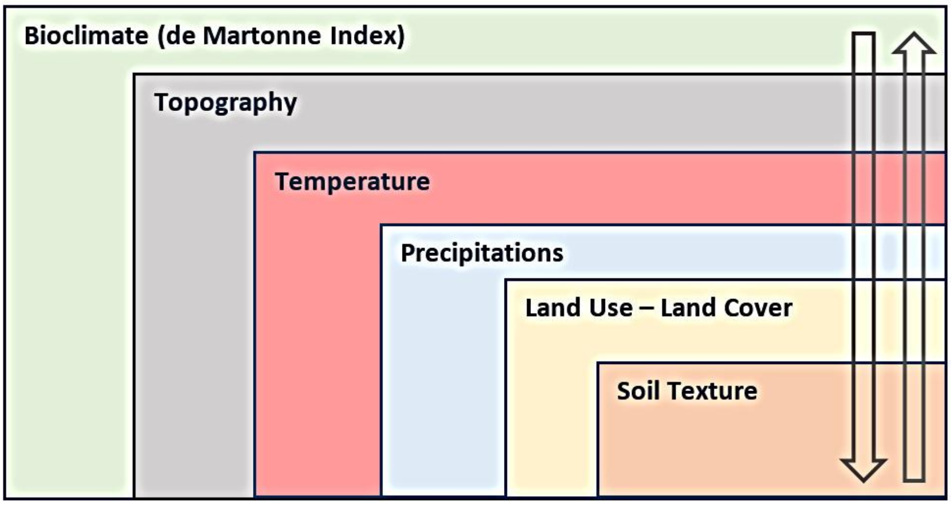

Figure 2. Conceptualization of the Ecosystem delineation using thematic layer superimposing after Metzger, et al., 2005

Often the wetlands are classified by one of the main physical characteristics, like topography: ex. floodplain wetlands or mountain wetlands. This classification is based mainly on expert decision regarding the importance of physical factors in wetland functionality. The same principle is used for EUNIS habitats classification (EEA 2015; Davies et al., 2004).

Principal Components Analysis (PCA) is the second method used in this study for mapping large scale distribution of wetlands. The working principle is to reduce the components values of the original dataset to smaller variables, and to analyze their distribution of variance (Wold et al., 1987; Demšar, 2013) in this case study, with the values from the selected thematic layers. PCA is a statistical method that eliminates the expert decision classification and it has been used in Romania in studies of climato-hydrology Zaharia and Beltrando 2007; Zaharia and Beltrando 2009), landslide hazards (Chițu et al. 2009; Mihai et al., 2014) and landscape functionality (Petrișor et al., 2012) and others.

The steps involved in PCA analysis for Romania's wetlands mapping consisted in:

- Layer data selection for PCA analysis;
- Analysis of the total variance explained by each component with significance for the model;
- Analysis of the eigenvector on the rotational matrix, to discriminate the component structure;
- Plotting the component distribution on the eigenvector graph, to interpret the results;
- GIS processing of PCA distribution;
- Mapping the Components contribution to spatial distribution of wetlands.

This method is a GIS based method, and has the advantage of being a more systematized procedure by analyzing layer parameters in a spatial context.

The results of the study are presented in the following section.

3 RESULTS

The geographical analysis, offered the basic information regarding the spatial distribution of wetlands characteristics in Romania. Some of the results are presented further.

More than 78% of the wetlands surfaces are located in the Danube Delta and Danube Floodplain, while on superior altitude, 96% of wetlands surfaces are positioned at heights lower than 300 m (Appendix 1, as example). By temperature 90% of wetlands are located in areas with average temperature higher than 10°C and by precipitations approximately 75% of wetlands receive less than 500 mm of rainfall per year. De Martonne Aridity Index indicates that 65% of the wetlands are located in dry and semi-dry regions, in steppe and forest-steppe environment. By soil texture, three classes predominate, peat, clay and mixed-texture, which indicate a great variety of the soil texture. The land use type indicate that 23% of wetlands are located in other land use than wetlands or water bodies that could indicate an anthropic origin of the wetlands.

The PCA indicates the manner in which the analyzed layers (topography, precipitations, temperature, the aridity index, land use and soil texture) contribute to the description of the wetlands, by association. From table 1 it can be remarked that only two components have eigenvalues above 1, and that these components explain 68% of the wetlands attributes. The first two components will be retained for analysis (Table 1).

In Table 2 is explained the manner in which the first two components are formed by the selected layer. It can be observed that the first component is formed mainly by climatic elements and the second component retains information only by the land management and soil texture type.

Table 1. The distribution of total variance - explained by layers

Component	Initial Eigenvalues			Extraction Sums of Squared Loadings			Rotation Sums of Squared Loadings		
	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %	Total	% of Variance	Cumulative %
1	3.027	50.451	50.451	3.027	50.451	50.451	3.026	50.429	50.429
2	1.065	17.747	68.198	1.065	17.747	68.198	1.066	17.769	68.198
3	0.932	15.532	83.730						
4	0.575	9.584	93.314						
5	0.238	3.959	97.273						
6	0.164	2.727	100,000						

Extraction Method: Principal Component Analysis.

In Figure 3 is presented in a plot the relation of elements with the two components, and how they are grouped. It can be seen that the temperature have a negative correlation with the other three elements, Topography, Precipitations and Bioclimate. The land use and soil texture are strongly related between them, by the fact that where the land use type is wetland, there is a specific type of soil texture (ex: sandy-lommy).

Table 2. Rotated Component Matrix[a]

	Component 1	Component 2
Bio_Climate	0.922	
Topography	0.910	
Precipitations	0.884	
Temperature	-0.741	
Land_use_Land_cover		0.763
Soil_Texture	0.104	0.689

extraction method: principal component analysis

rotation method: varimax with kaiser normalization.

a: rotation converged in 3 iterations.

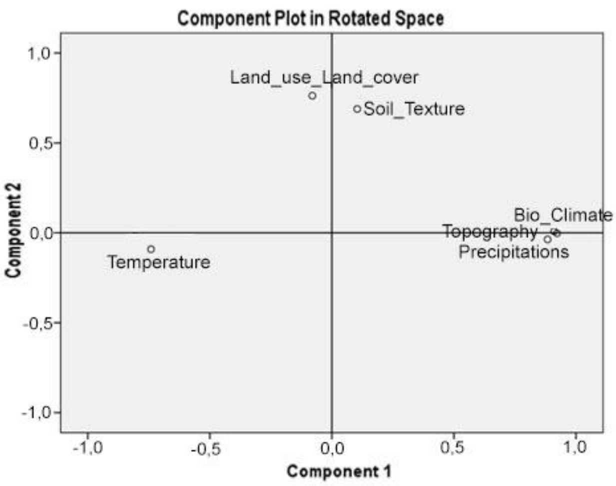

Figure 3. The components structure by layers

The results of the PCA analysis are presented bellow as maps in Figure 4 and Figure 5. The component 1 has a major contribution to the attributes of wetlands in the Danube Delta, Balta Marea a Brăilei wetland, Comana Wetland, Lacul Sărat wetlands and others, mostly on the natural wetland structure. The component 2 has a greater presence on the internal rivers (Siret, Olt, Mureș rivers floodplain) and especially along the great river engineering works, as dams or dikes constructed along these rivers. In this regard, the wetlands from the great dams of Romania (ex: Izvorul Muntelui Lake,– Bistrița River, Vidra Lake- Lotru River) have attributes that are described best by Principal Component 2.

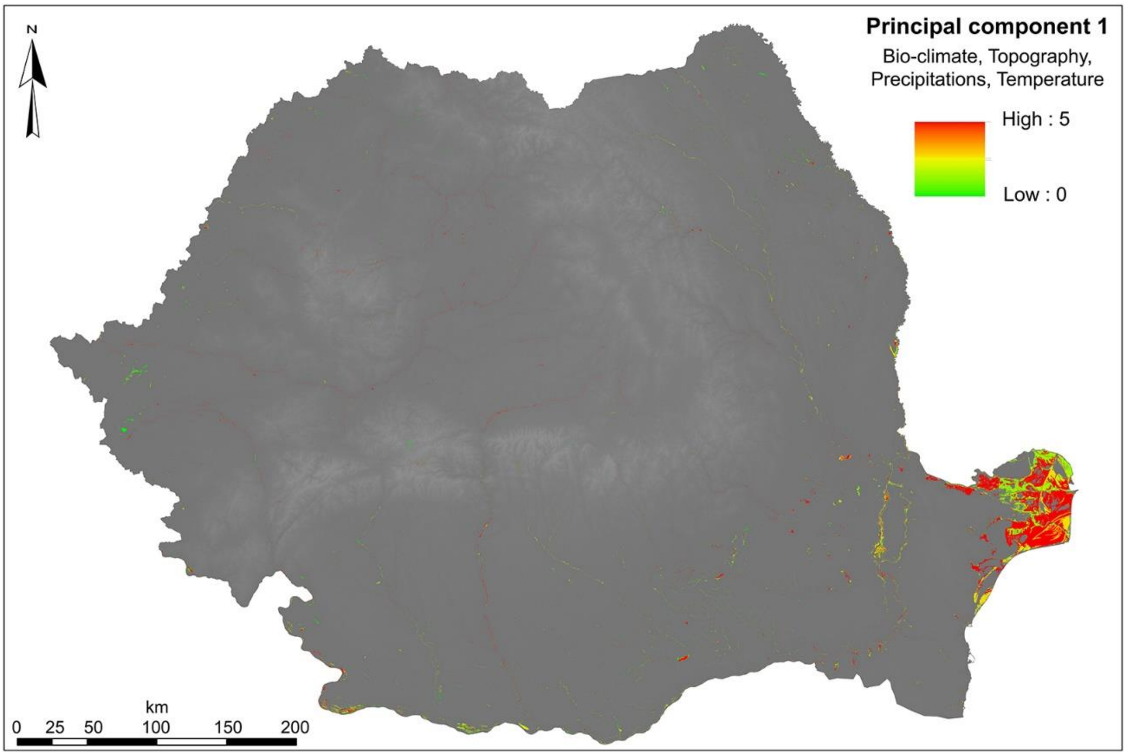

Figure 4. Distribution of Principal Component 1 in the Romanian wetlands

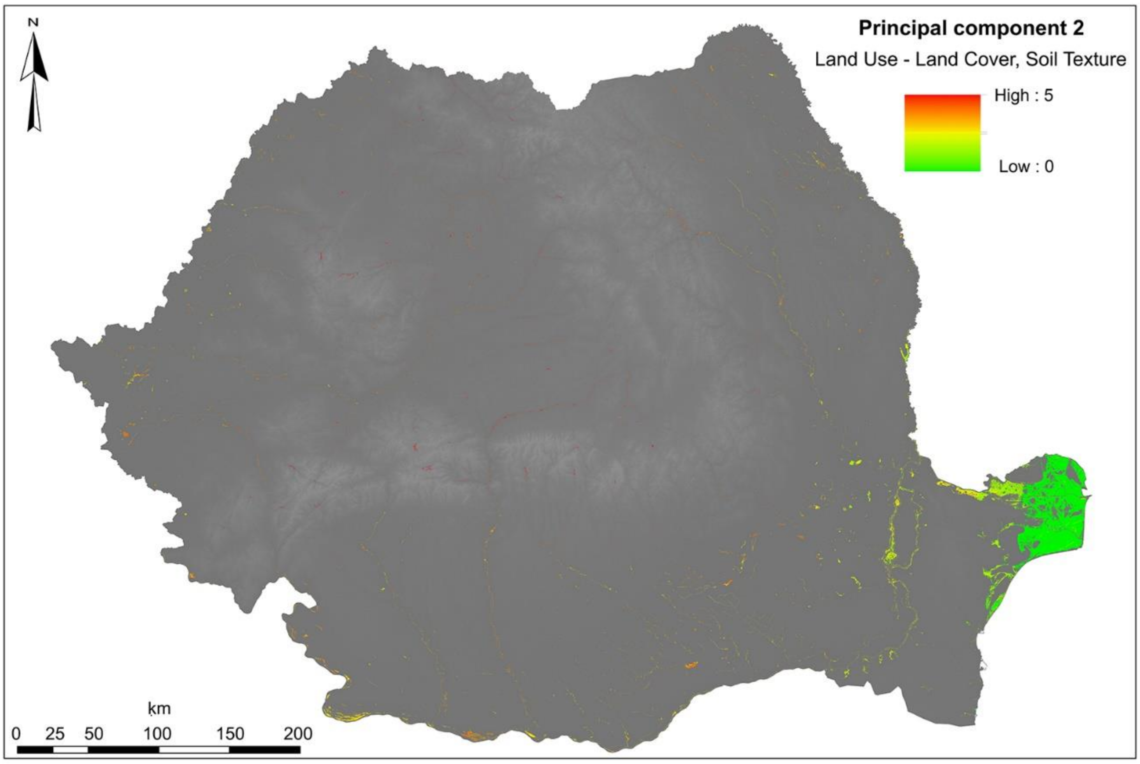

Figure 5. Distribution of the Principal Component 2 in the Romanian wetlands

The components were scaled from 0-5 in value, in regard to their contribution to the wetland functionality and description. If a component has for a wetland a value of 2 the other component describes the rest of the attributes, resulting that the two components are complementary. Also the analysis could be carried for more than six layers and for more than two components, if these components have a relevant contribution to the description of the wetland.

CONCLUSION

The wetlands are ecosystems in a continuous change due to the anthropic pressures and environmental changes related to it. In Romania more than 3800 km^2 are forming the wetland surfaces, which are located mainly alongside the Danube Floodplain and in Danube Delta. Most of the wetlands from Romania have a dry or a semi-dry climate, favorable to the development of reeds instead of riparian forests. A geographical analysis does not distinguish between the most important attribute in a wetland area, hence the PCA analysis come to enhance the methods of describing and mapping the wetlands and to eliminate the expert decision subjectivism.

By applying the PCA analysis on the six thematic layers chosen from the geographical analysis it can be noticed that the climatic factors (temperature, precipitations, de Martonne Aridity Index) and the terrain are grouped in a principal component while the second component is formed by soil texture and land use. In other words, the first component is specific to the natural wetlands while the second component is specific to the artificialized wetlands, near the lakes of dams.

The results of this method can offer support in understanding the changes that occur in the wetland functionality at a large scale, by its ability to capture the spatial patterns of changes.

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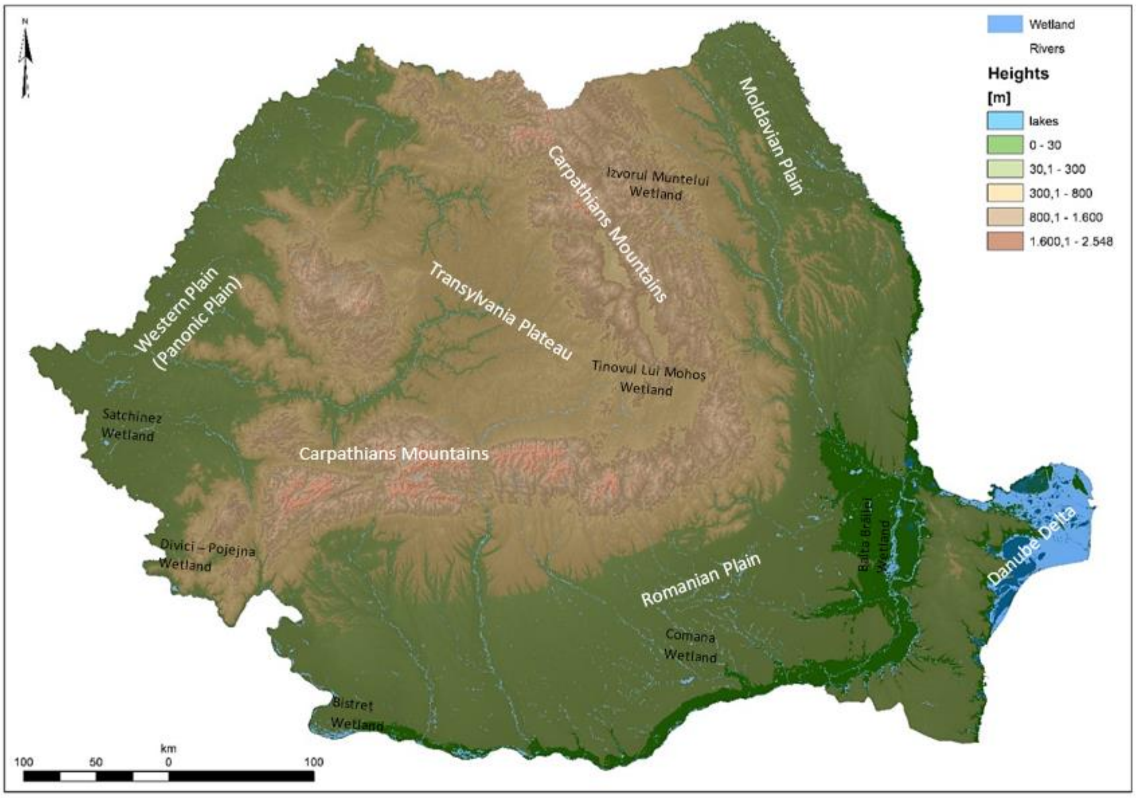
Appendix 1



Romania’s wetlands distribution by topographical units

Wetland distribution by topographical units

No.	Region	Surface [km^2]	Proportion of the total surface [%]
1.	Danube Delta and Balta Mică a Brăilei wetland	2380	61.6
2.	Danube Floodplain without Balta Mică a Brăilei wetland	655	17.0
3.	Plain areas	685	17.7
4.	Hilly areas	132	3.4
5.	Mountainous areas	9	0.2
6.	Total	3861	100.0