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Estimation of ecohydrographical regions in Slovenia

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ABSTRACT: The European Union Water Framework Directive (WFD) provides the framework for the protection and improvement of the aquatic environment. Surface water bodies should be classified into categories and differentiated according to types in the chosen category. A draft of differentiation of rivers and lakes in Slovenia into types of ecohydrographical regions is presented in the paper.

The WFD provides two kinds of differentiation on surface body types: system A according to Illies (1978) with ecoregions on the relevant map in Annex XI of WFD, and system B. System B gives the grounds for consideration of specific country conditions according to obligatory and optional factors. The same degree of differentiation should be achieved by System B as is by System A.

System B implements ecohydrographical regions according to obligatory factors (descriptors). The country is subdivided into seven ecohydrographical regions: three in the Adriatic Sea river basin and four in the Danube river basin. Watershed borders determine the dividing lines of ecohydrographical regions. The main factors for determination of ecohydrographical regions are altitude and geology with predominant karst phenomena. Major rivers with watersheds larger than 1000 km^2 are treated individually. Small rivers with catchment of less than 100 km^2 are differentiated according to ecohydrographical regions. The optional descriptor then determines types of rivers (both major and small): transport of sediment. The types of river are developed by GIS and 3D-models of a river network.

KEYWORDS: WFD, aquatic environment, water bodies types, ecohydrographical region

Introduction

The Water Framework Directive has entered into force and until the year 2015, the different categories of surface water bodies: rivers, lakes, and transitional and coastal waters should achieve good surface water status, EU 2000. The categories of water bodies are differentiated into types and their ecological status is described according to the water body type.

For differentiation of water bodies into types, a country can choose between two systems: System A with ecoregions in accordance with the relevant map enclosed in the annex of WFD, or System B with the same degree of differentiation and by using non biotic obligatory and optional descriptors. Specific biological reference conditions should be developed for each water body type. In the paper, only the differentiation of rivers is discussed, because there are only two natural lakes and several artificial lakes with a surface area larger than 0.5 square kilometres in Slovenia. Also, the coastal and transitional waters are practically in one region, EU 2000.

System A should be developed in accordance with the research carried out by Illies (1978) and presented on the map in Annex XIA of WFD (EU 2000). Entire Europe is presented on the map and, accordingly, it is quite rough. We transposed it into a smaller scale map with four ecoregions: the Alps, the Dinaric western Balkan, the Hungarian lowlands and Italy, (Figure 1). The question is, whether we should consider only two regions: Alps and Dinaric western Balkan. System A also includes some obligatory descriptors: size of watershed, altitude and geology.

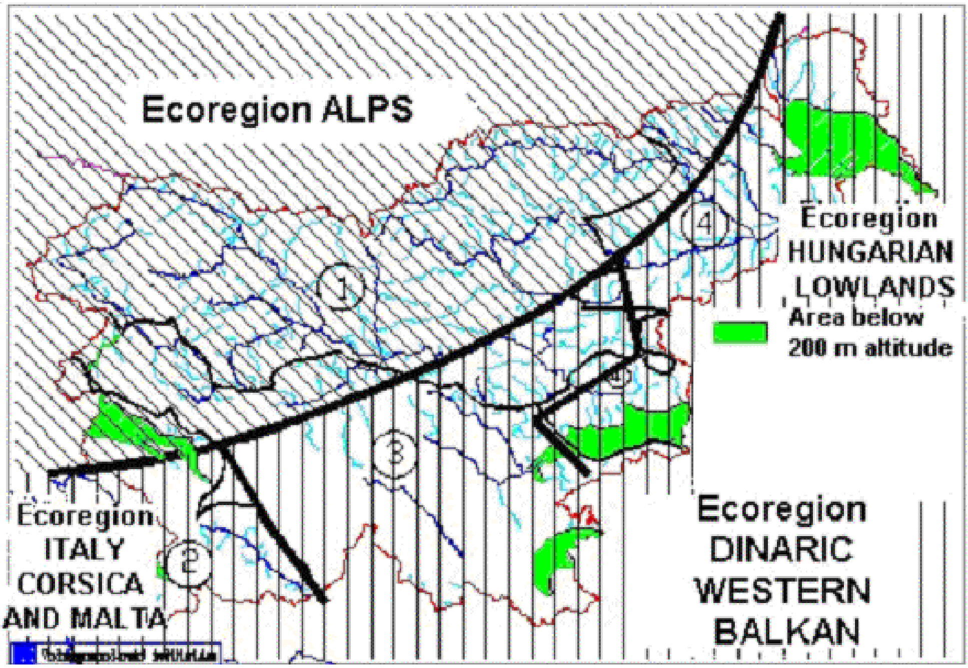

Figure 1. Ecoregions in Slovenia by Illies 1978.

Differentiation according to the variant with two regions: Alps and Dinaric western Balkan have 17 river types, and the variant including all four regions has 26 river types, Brilly et al. 2000. The ecoregions of System A do not fit to major river basins that in Slovenia belong to the Danube and Adriatic Sea river basins, this being the main reason for development of System B.

Methods

System B is more flexible and considers specific natural conditions. The differentiation should consider obligatory descriptors and such optional descriptors that enable the identification of specific biological conditions, Table 1, EU 2000. The degree of differentiation should be the same as in the differentiation using System A.

The rivers are separated on Figure 2 according to the watershed size, by using the country coding system (Brilly 2000; Šraj, 2001). The sizing of river bodies with large dividing lines of the river basins is done automatically with GIS and an associated database. The coding system does not allow the separation of smallest river bodies with watershed area of less than 10 square kilometres.

Therefore the computer application RiverTools was chosen for an automatic determination of a drainage basin and the making of "synthetic channels" on the basis of a generalized digital model of relief DMR25, Research systems, 2001. The computer program is based on the principle that the water runs from a gravitationally higher elevation towards a lower elevation or from a higher cell into a lower one. As the basis for the calculation the DMR25 was used with the linearly interpolated cells at 100 x 100 m. The program enables the automatic determination of a vectorized hydrographic network, which is linked into a topologically oriented whole according to the size of the drainage basin. With such network, several special operations can be carried out, such as the determination of the Area-Distance Function of the drainage basin, longitudinal cross-section, elimination of reaches with specific slope etc.

Table 1. System B according to Annex II, EU 2000.

Alternative characterisation	Physical and chemical factors that determine the characteristics of the river or part of the river and hence the biological population structure and composition
obligatory factors	Altitude latitude longitude geology size
optional factors	distance from river source energy of flow (function of flow and slope) mean water width mean water depth mean water slope form and shape of main river bed river discharge (flow) category valley shape transport of solids acid neutralising capacity mean substratum composition chloride air temperature range mean air temperature precipitation

The network of water bodies determined by calculations was compared to the measured data of the network, Figure 3. Data have shown that there are no significant deviations and that the results given by the calculated network can be transposed to the actual network with a simple GIS operation, i.e. transposing the data and information from one network into another.

While implementing System B, the following has been taken into account:

- Studies on composition and abundance of fish fauna in Slovenia (Bertok et al., 2000), sharply dividing the country into the part belonging to the Adriatic Sea River Basin and to the part belonging to the Danube River Basin.

- Several geographic and terrestrial biological studies of Slovenia divide the country in several ways, however, they all include the renowned, wide, and specific karst region in need of special treatment, (Mršić, N. 1997, ZRC SAZU 1998 and OGFF, 2001)
- the official country monitoring providing data about biota in major rivers.

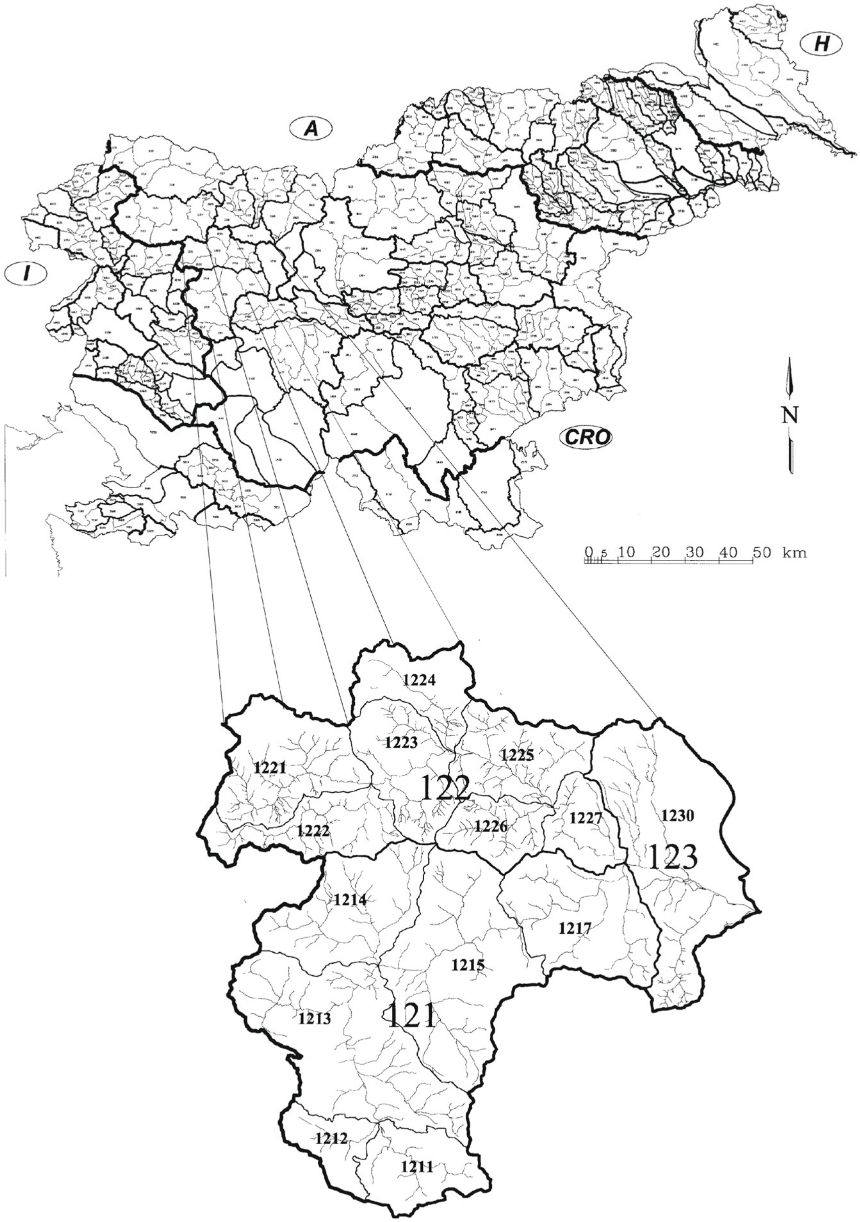

Figure 2. The River watershed coding system in Slovenia (Šraj, M., 2001).

Figure 3. Calculated and digitised network.

Development of ecohidrographical regions

The majority of river water bodies are in the categories of medium and small rivers that are outside the official country monitoring system. Moreover, the small water bodies are closely related to the nearby terrestrial ecosystems, and are dependent upon them. The country is thus subdivided into regions, namely into ecohydrographical regions for differentiation of small and medium rivers. Large rivers were differentiated separately according to water regime and monitoring data.

At first, the country was divided into two river basins: the Adriatic Sea river basin and the Danube river basin, according to the fish habitat data and studies, (Bertok et al. 2000).

The studies have shown that in the Slovenian part of the Adriatic Sea River Basin there are 8 endangered fish species, and in the Slovenian part of the Danube River Basin there are 38 endangered species, this being the criterion that has to be considered in achieving a higher ecological state. The Slovenian part of the Adriatic Sea River Basin has 14 endemic (non-indigenous) species, and the Danube River basin 11, respectively, which can become a criterion in achieving a higher ecological state. The Slovenian part of the Adriatic Sea River Basin has 2 endemic species, and the Danube River Basin 7, this possibly being the criterion for establishing the sampling type of a water body. The Slovenian part of the Adriatic Sea River Basin has 21 indigenous species, and the Danube River Basin 52 species, which is important for determination of the sampling type of a water body.

The ecohydrographical regions defined in accordance with the previously given points of departure and the obligatory factors (Table 1, Figure 4) are:

1. Alpine ecohydrographical region of the Adriatic Sea River Basin; Mountainous region with elevation of up to 800 metres, mountain peaks under 2500 metres, humid climate with more than 2000 mm precipitation per year, high low flows with 10 lit/s/km^2, calcareous permeable geological formations, and forest line below 1600 m.

2. Alpine ecohydrographical region of the Danube River Basin; Mountainous region with an elevation of up to 800 meters and peaks under 2500 meters, humid climate with

more than 2000 mm precipitation per year, high low flows with 10 lit/s/km^2, calcareous permeable geological formations and forest line below 1700 m.

3. Karst ecohydrographical region of the Adriatic Sea River Basin; Hilly region between 200-1000 metres of elevation, humid climate without surface waters, specific karstic hydrological regime, calcareous permeable geological formations.

4. Karst ecohydrographical region of the Danube River Basin; Hilly region between 200-1000 meters of elevation, humid climate without surface waters, specific karstic hydrological regime, calcareous permeable geological formations.

5. Subalpine ecohydrographical region; Hilly region between 200-800 metres of elevation, humid climate with 1400 mm precipitation per year, semi-permeable calcareous and siliceous geological formations.

6. Hilly and plain ecohydrographical region; Hilly and plain area below 400 metres, semi-arid climate with precipitation below 800 mm, permeable calcareous and siliceous semipermeable and permeable alluvium formations, specific low flow is below 1l/s/km^2, area of water scarcity.

7. Mediterranean ecohydrographical region; hilly area below 400 metres, Mediterranean climate, non-permeable siliceous formations.

"white surface" area of permeable calcareous karst formation without surface water is included in the Mediterranean region, because the waters collected there partly flow through the Mediterranean region; area of water scarcity.

The final differentiation of river water bodies has taken into account additional optional factors: the transport of solids and mean substratum composition. The mean substratum

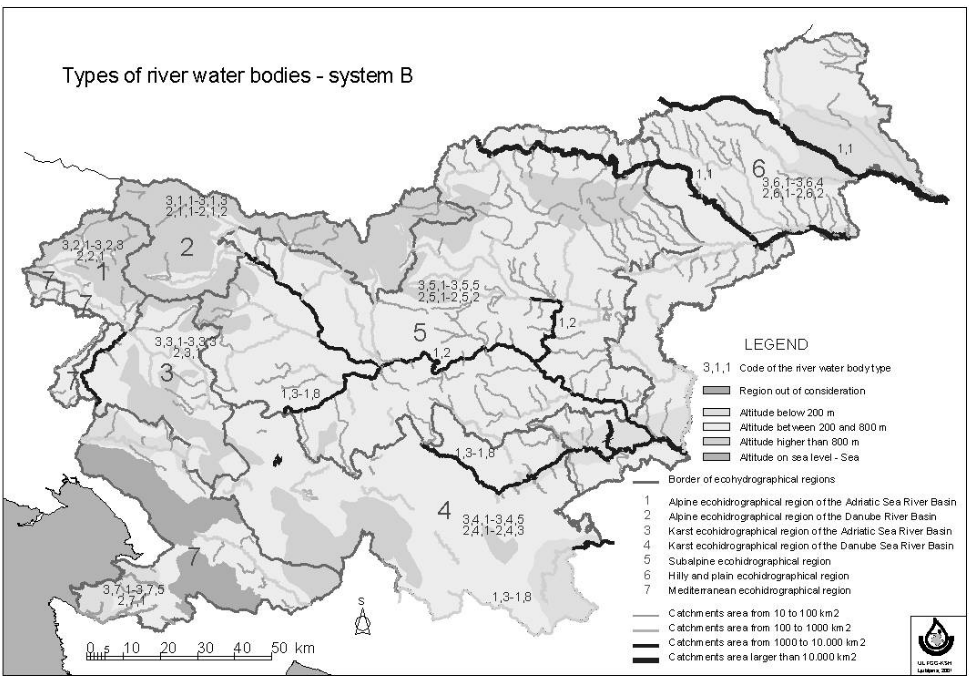

Figure 4. Ecohydrographical regions

composition includes the integrated influence of other optional factors, such as: distance from river source, energy of flow (function of flow and slope), mean water surface width, mean water depth, mean water slope, form and shape of main river bed, river discharge, category valley shape, and transport of solids. The criterion used for differentiation among types by means of substratum composition is a matrix that includes compact rocks, gravel, sand and silt. The second optional factor, i.e. the transport of solids, similarly integrates the influence of other factors, such as the mean composition of substratum. The criterion for differentiation is the yearly transport of solids. With regard to riverbed composition we differentiate between parent rock, gravel, sand and silt. In terms of bed composition and stream slope data from the literature were considered according to Kinori et al. (1984). In calculations the sediment density of 2650 kg/m^3 was considered, Reynold's number larger than 500 and water depth of 10 cm. Thus, the critical grain size and stream slope were calculated, Table 14. The elimination of classes of rivers with regard to stream slope were in a simple manner determined by way of the RiverTools. Table 22 also gives data on river lengths for each class.

Table 2.

d_{cr} critical diameter of grain size in mm	stream slope	bed composition	length in km
>100	>0,1	substratum matrix	33,17
100-1	>=0,001 <0,1	gravel	4.326,42
1-0,1	>=0,0001 <0,001	sand	162,23
:<0,1	<0,0001	silt	84,57

Large rivers are differentiated into:

(1.1) The Drava and Mura rivers are major rivers with a drainage area outside of Slovenia on more siliceous rock, with a pronounced hydrological snow regime, gravel bottom and sediment load.

(1.2) The Sava river (in entire length up to the border with Croatia) and the **Savinja** (downstream from the confluence with the Dreta) have a calcareous drainage area with a pronounced hydrological rain–snow regime, the stream bed is covered in gravel, sediment load is present.

(1.3–1.7) The Ljubljanica, Unec, Krka and Kolpa rivers fall according to their basin composition within the Karst region. However, they have different composition of river bottom along their course and in certain reaches the sediment load is disconnected. They are comprised of several types (5–6) according to riverbed composition (4) and sediment load:

(1.3) gravel with sediment load (the Kolpa)
(1.4) gravel without sediment load (the Ljubljanica)
(1.5) sandy gravel without sediment load (the Krka)
(1.6) sand with sediment load (the Unec)
(1.7) silt without sediment load (the Ljubljanica).

(1.8) The Soča river downstream from the confluence with the Idrijca river is a strongly modified water body and a type of its own.

The river lengths and the number of types of ecohydrographic areas are shown in the Annex and on Table 3.

Table 3.

Ecohydrographical Area	No. of types	Stream length (in km)
Number of types of large streams	8	
1. Alpine ecohydrographical region of the Adriatic Sea basin	3	133.43
2. Alpine ecohydrographical region of the Danube basin	3	313.76
3. Karst ecohydrographical region of the Adriatic Sea basin	3	186.73
4. Karst ecohydrographical region of the Danube basin	4	549.54
5. Perialpine ecohydrographical region	3	1,887.75
6. Plain and hilly ecohydrographical region	5	1,230.19
7. Littoral ecohydrographical region	4	304.99
TOTAL	33	4,606.39

Conclusion

1. The investigation has shown the exceptional possibilities of the RiverTools programme, DMR and GIS in determination of drainage areas of streams and their characteristics. Furthermore, GIS enables a simple determination of lengths of respective types and their display on the map.
2. Number of river types presented in Table 3 is the maximum expected number according to non-biotic factors. Further field investigations should integrate some of the types according to biological monitoring.

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