A GIS based assessment of hydropower potential in Hornád basin

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The issue of efficient use of hydropower, ones of the available renewable resources is currently in the process of sustainable development of each country, often addressing the issue. Incite multiple aspects. It is now seen just growing interest in exploiting the potential of hydropower. On the basis of active efforts are developed to map the total quantity of usability hydropower at basin level in Slovakia. GIS as a powerful and sophisticated tool for processing spatially localized information and offers support for renewable energy sources (not excluding the field of hydropower). Through the integration of spatial data allows assessing the real problems and thus contributing effectively to make rational decisions. Especially in the field of hydropower projects have GIS well founded importance. Of course is important to mention that the potential for hydroelectric power is useless without the operation of hydropower that converts water into electrical energy. For the needs of administrators of watercourses and operators of water systems, the proposed model can be an important tool for decision-making in relation to its implementation activities. Contribution to the design solutions for potential hydropower will address river basin Hornád.

Key words: *Corine Land Cover, hydropower plants, small hydropower, hydropower potential*

Introduction and background

Question renewable resources and their utilization is still a current topic of social events. Hydropower represents only a certain amount of energy, which has the planet. The water in the country is significantly dynamic element that carries energy, material and information in the basin. Water is an irreplaceable natural resource, essential for life. Its movement depends on the environment, e.g. by country (www.1). Using the potential of watercourses is currently a hot topic. Energy from hydropower it can make to building energy independence on other sources and thus contribute to economic growth mainly of small parts. Following economic and social development of a tainted past so far failed to enforce the use of hydropower for energy fully and effectively. It needs to realize that the situation in the field of fossil fuels is quite pretty poor vision and future developments are inclined to their exhaustion. The central location of Slovakia to the European continent, as well as its morphology is the determinants of the size and distribution of hydropower potential in Slovakia. Slovak territory runs one large river Danube with energy usable length (in the Slovakia) 172 km. Other rivers mainly in Slovakia as it flows out from the stem overall length of recorded flows in Slovakia is 49 755 km. Length of important water management and water flows in Slovakia is 9183 km. A significant proportion of hydropower is due to the nature of the terrain scattered in small rivers, whose energy is only usable in small hydropower plants of less than 10 MW. The content of contribution of will be given to the identification of usable hydropower potential of river Hornád applying GIS tools, therefore the following Table. 1 presents the technical exploitable potential of the basin [1].

Tab. 1. Technically exploitable potential of selected river basin – Hornád.

The hydrologic basin	**The total theoretical hydropower potential**	**Technical hydropower potential**
[GWh.year^{-1}]		
Hornád	807	262

Source: The concept of using hydropower potential of rivers in Slovakia into the 2030 [2].

The use of hydropower has environmental and economic benefits for each country. Hydropower is more environmentally friendly than other major source of electricity using fossil fuels. Hydroelectric power plants do not produce heat, gases, etc. Extractions of fossil fuels to other energy sources are also a significant negative impact on the environment (www.2).

Water plants are suitable as regulatory or backup power in the power system and are also suitable in terms of the use of primary energy sources, which are located in our area. Hydroelectric power is usually set as hydro work that fulfills multiple purposes, the importance of energy or may not be a priority. [6]

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Hydropower was referred to as a source of energy, which allows to generate electricity without using fossil fuels, and they are not then part of the emissions from electricity generation (www.3).

Efficient use of hydropower resulting from the usable hydropower potential (www.4). The efficient use hydropower is necessary to effectively use gradient of water. Determining the potential of hydropower is not a simple matter. It requires a certain number of required expertise and practical experience. Therefore, the contribution of the methodology is for promoting the application of GIS tools. Using the potential of hydropower can contribute significantly to environmental and sustainable energy supply. This objective, however, still requires a lot of effort in research and development. On the one hand, it is important to further develop the various techniques that have been (at least partially) developed to the stage of permitting their use and verify the above prerequisites for sustainable use of water power.

Possibilities of using hydropower

Man uses the power of water for a long time. In Slovakia, the energy for many years gaining the right of watercourses (www.5). Use of water power (energy streams) is from ancient times to the basic source of energy production. Hydropower potential of rivers thus belongs to valuable natural resources of each country. Its use for the production of electricity through hydroelectric power in different countries and different continents. The determining factor is just natural conditions and the degree of economic, technological and economic development of the country. Advanced European countries (e.g. Germany, United Kingdom, Norway and Finland) construction of hydropower dedicated close attention. Hydropower potential of its waterways used from 65 % to 95 % and the construction of hydroelectric installations continue. In the Czech Republic hydropower potential uses to 34,2 % in Slovakia to 56,4 % despite optimal natural conditions [3].

Slovakia is among the countries that have very good conditions for the production of electricity from hydro sources. The possibility of realizing them is through small hydropower (SHP). This potential, however, while we use only about a quarter, which is a pity. It is in fact, in contrast to solar or wind power, a relatively stable source of supply of electricity. In addition, hydro potential, or energy contained in the water flow, is the property of the Slovak Republic. Nobel primary energy - water - is not dependent on imports from other countries, as is the case with far too exploited energy resources - gas, oil, coal, nuclear fuel [4].

Potential rivers in eastern Slovakia in the future may use the proposed 19 small hydropower plants. By 2020, the river Poprad, Bodrog, Hornád and these should cover the total installed capacity of 5,55 MW and an average annual production 27,74 GWh. Most are located in the Košice region, where it is possible for the Bodrog River Basin and Hornád construct small hydropower plants with a total output 3,24 MW and the expected production of electricity 15,4 GWh. The rest are proposals for the construction of small hydropower plants along the river Poprad with an installed capacity 2,31 MW the expected production 12,34 GWh (www.6).

Development and review SHP in the Košice Basin

SHP played a very important role in the early days of electrification with us. The following Table 2 gives an overview of SHP located in the Košice Hornád Basin.

Tab. 2. Short overview SHP in the river basin Hornád [5].

Name of SHP	Type (category)	River	Length of the river [km]	Power of SHP [MW]	Average annual production [MWh/year]
Chrasť nad Hornádom	flow-through	Hornád	116,80	0,16	0,838
Markušovce I	flow-through	Hornád	125,20	0,13	0,623
Markušovce II	flow-through	Hornád	120,85	0,11	0,516
Breziny	flow-through	Hornád	58,20	0,58	2,785
Smižany	flow-through	Hornád	136,70	0,10	0,514
Spišské Vlachy I	flow-through	Hornád	107,40	0,15	1,17
Družstevná pri Hornáde	flow-through	Hornád	45,70	0,44	1 983
Košice - Ťahanovce	flow-through	Hornád	37,20	0,44	2 145
Krásna nad Hornádom	flow-through	Hornád	26,50	0,16	580
Krompachy I	flow-through	Hornád	98,60	0,33	654
Krompachy II	flow-through	Hornád	99,70	0,11	384
Spišská Nová Ves	flow-through	Hornád	133,20	0,03	0
Vyšné Opátske	flow-through	Hornád	29,90	0,63	0

New trends for search sites for SHP

Locations for the use of water power are in the Slovak Republic mapped individual trustees basin. This is information that is not publicly available and obtaining them is often time-consuming and expensive event. The construction of small hydropower plants is preferably used locations in which the operation was carried water mills and sawmills [5]. The new location is necessary SHP perfectly prepared. This preparatory phase is significantly underestimated, even if the process itself plays an important meaning. In this part should be based on preliminary information to make relatively very precise evaluation properties SHP for the actual implementation. Given that life SHP is planned for decades, any underestimation can have lasting consequences. It is therefore recommended consulting closely with experts - hydroelectricity. Contribution to the implementation of SHP is to make the following observations:

- legal relations of equity,
- technical - water ratios,
- nature protection,
- the interests of monument protection,
- research area,
- public opinion, if construction directly affect intra-urban (built-up parts of) communities.

Hydroelectric power is a function of gradient and flow. That is, the power plant on a small stream, which, however, able to use gradient above one hundred meters, may have a higher power than the power of the great river basin [7]. The key indicators for valuation selected locations (for use hydropower potential) are placed on the two basic parameters:

1. usable gradient,
2. flow.

Those parameters are processed for the profile, which is projected use of SHP. ***Gradient*** is a level difference of water levels [8]. ***Flow*** rates the amount of water in that the useful profile [5].

Geographical coverage of the Hornád River Basin District

River Hornad creates the second largest river system in Eastern Slovakia. In Hungary at the Onoda, Hornad flows into the salty and after a few kilometers flows into the Salt Tisza, which is the largest tributary of the Danube. The total catchment area is the Hornád 5 436 km^2, from that in Slovakia there is a sub-basin with a area 4 414 km^2. Sub-basin 4-32 Hornád in Slovakia is divided to:

4–32–01 Basin Hornád after Hnilec
4–32–02 Basin Hnilec
4–32–03 Basin Hornád from Hnilec after Torysa
4–32–04 Basin Torysa
4–32–05 Basin Hornád after Torysa (Figure 1).

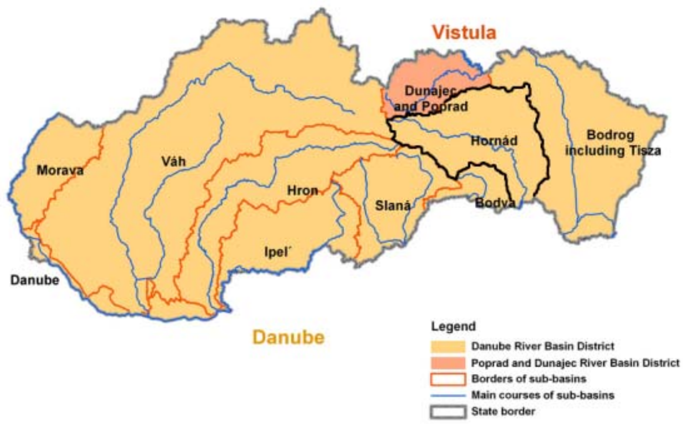


Fig. 1. River basin districts of the Slovak Republic and their sub – basins. Source: www.vuvh.sk

Objective

The main objective of this paper is visualizing the possibilities of GIS tools in relation to the possibilities of monitoring the hydro energy potential of selected river basins Hornád.

Methodology

The methodology is based on the using tools of GIS. The resulting bottom-up energy storage potential of the prospective SHP schemes was added to provide a country potential for each topology [9]. The issue for search hydropower potential is necessary based on the compilation model, which will form:

- DEM (Digital elevation model) - which is a topological description about:
  - all date fed by information about scenarious
    - river system,
    - political borders,
    - administrative boundaries,
    - SHP with the existing spatial information,
    - NATURA 2000,
    - Landuse.

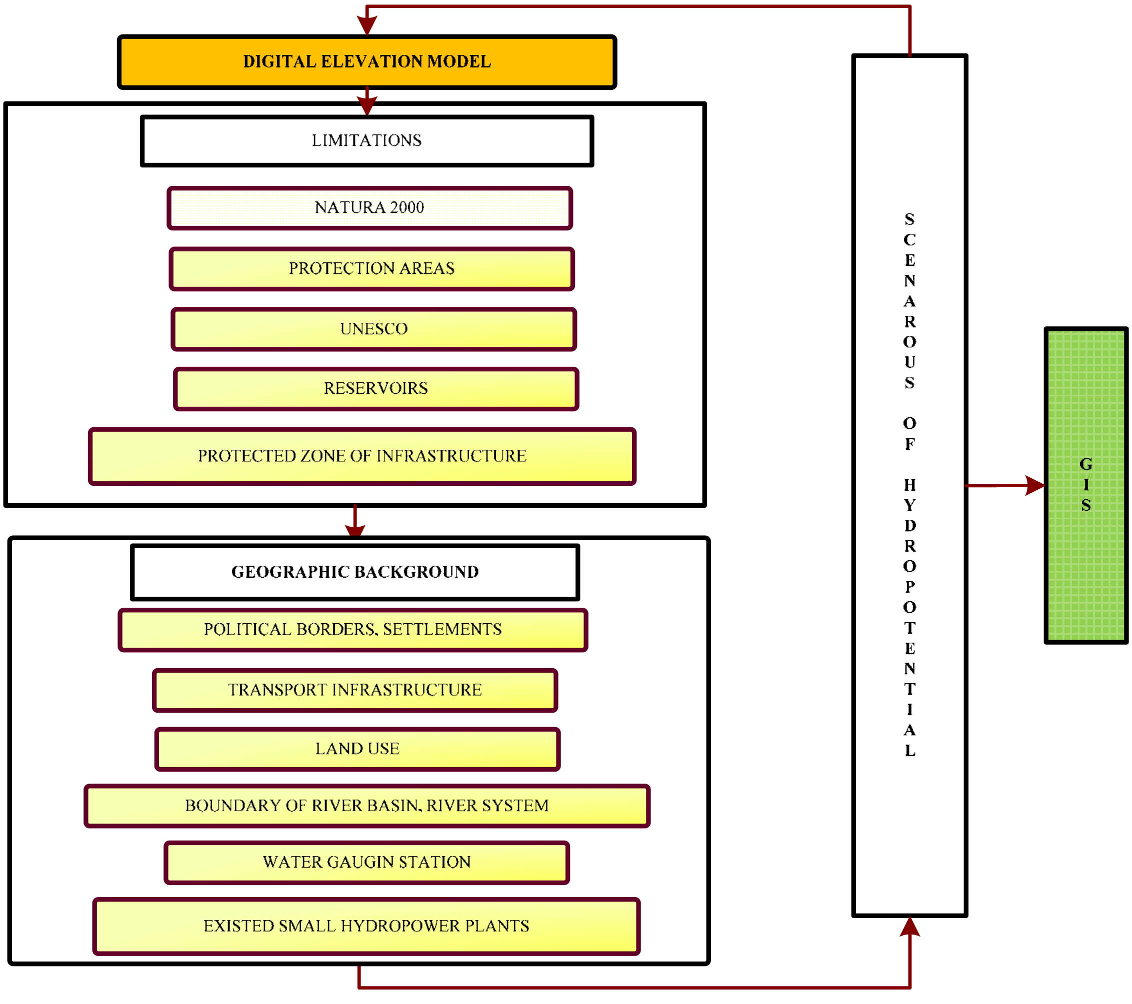
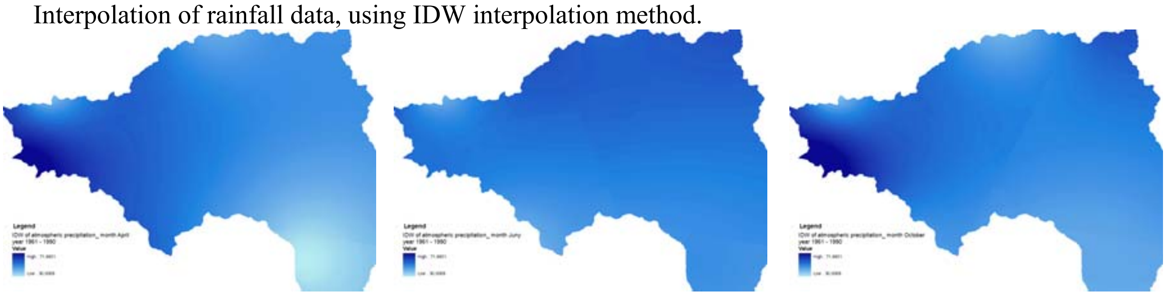


Fig. 2. Methodological information processing (methodological flowchart with the inclusion of intermediate potentials) [10].

The presented data layers were obtained by digitizing process underlying maps in ArcGIS 9.3 Source of certain documents was obtained from the official website of state administration. Processes for analytical processing was used Spatial Analyst, through which was implemented:

- Interpolation of rainfall data, using IDW interpolation method.



a) April b) Jun c) Oktober

Fig. 3. Interpolation average monthly precipitation values for the period 1961-1990.

Normally the process of processing and evaluating information on the amount of precipitation than the statistical methods used by the interpolation method. Together we create a mathematical basis for data processing by presenting rainfall generally [11]. For purposes of determining the amount of precipitation development is appropriate to apply the following methods:

a) Method of Thiessen polygons,
b) IDW,
c) Spline interpolation,
d) Bilinear interpolation,
e) Cubic interpolation [11, 12].

In the issue of observing developments rainfall conditions with the selected interval years 1961-1990 [13] in the river basin Hornad have been applied IDW method in GIS environment (Figure 3a, 3b, 3c). The advantage of using IDW method in processing meteorological data is that each cell of grid is a weighted linear combination of the values measured for automated monitoring stations assigned a value according to a mathematical formula [14]:

$$Z(s_0) = \frac{\sum_{i=1}^{n} \frac{Z(s_i)}{d_{0i}^{\beta}}}{\sum_{i=1}^{n} \frac{1}{d_{0i}^{\beta}}} \qquad (1)$$

where: $Z(s_0)$ the value of the interpolated point,
$Z(s_i)$ the value measured in the i-th point,
d_{0i} the distance between the interpolated point and the point of measurement,
β the degree of exponentiation scales.

Proposed model can also be integrated into the environment and personal geodatabases, which is fully supported by the software ArcGIS 9.3. The advantage of processing through personal geodatabases, you can create SQL queries [15].

Basic characteristics data layers of environmental constraints

- Digital elevation model (DEM) will present a topological description of the area (the real landscape in raster - GRID presentations) through the SRTM DEM, created a national coordinate system. Detailed description is presented in the following Table 3.

Tab. 3. Basic characteristic of DEM.

Territory	**Grid** [m]	**ap projection**	**FormAT**
Slovensko - Povodie Hornádu	100	Křovák (S-JTSK)	GeoTIFF

Other basic parameters:
1 cell of raster = 100 x 100 meter

SRTM (Shuttle Radar Topography Mission) DEM a unique product of the digital terrain model, which was created under the American project led by organizations NASA a NGA. For the Process of further processing, the model is suitable for analysis by GIS tools. His presentation states Figure. 4. (www.7).

Other supplementary information necessary for the treatment process will include the information referred to Figure. 5. All supplementary data will be

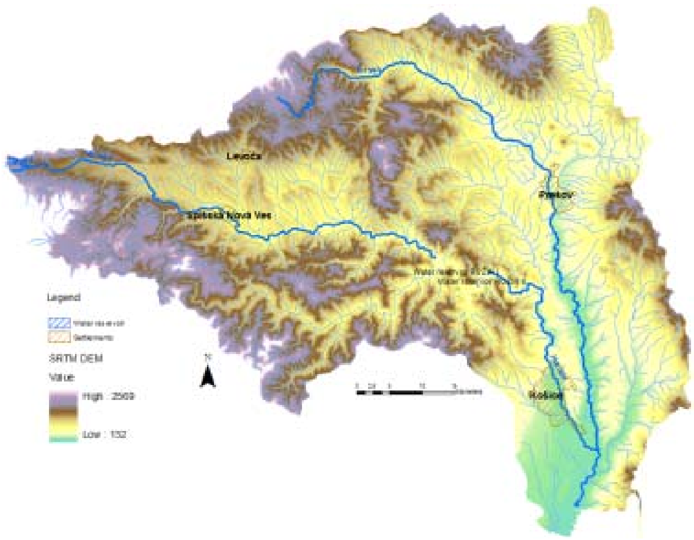


Fig. 4. Presentation of DEM for selected area.
Source: Data provided and processed by © GISAT (2007)

processed in the form of shp. files in GIS environment. In the processing will be integrated spatial information and taking into account geographic location gauging stations located in the territory concerned. Processing of information available on the gauges will show gradient and flow ratios river system. Information on flow rates are taken from reports available at Slovak hydrometeorological institute.

- NATURA 2000

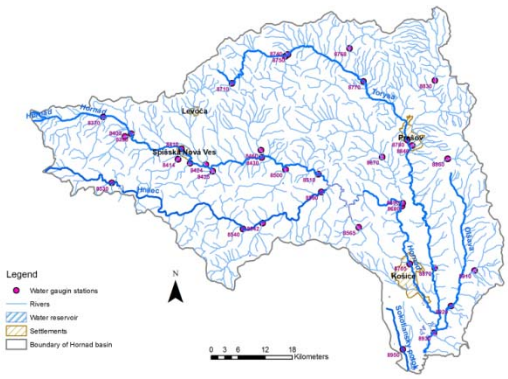
Is the name of the system of protected territories of the Member States of the European Union and its main objective is the creation of conservation of the natural heritage, which is important not only for the Member State concerned, but especially for the EU as a whole. This system of protected areas to ensure the protection of the rarest and most endangered species of wild plants, wildlife and natural habitats occurring in the territory of the European Union and by protecting these species and habitats to ensure the conservation of biological diversity across the European Union.Natura 2000 is a title for a network of protected sites of the European Union member states. The main reason for establishment of the network is an effort to maintain European natural heritage. By means of the NATURA 2000 network of protected sites, the protection of the most rare and endangered wild flora, wild fauna species and natural habitats within the area of the European Union should be provided. Through the protection of the species and habitats of European importance, EU biodiversity should be maintained [16].

- UNESCO - World heritage sites in Slovakia

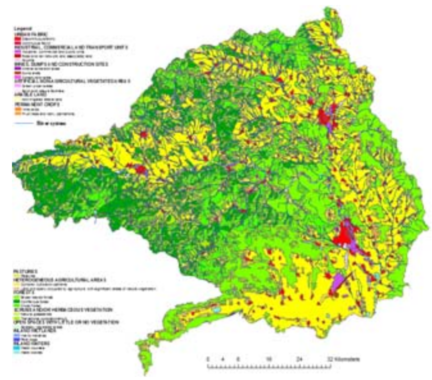
The long years of efforts to protect the most valuable natural and cultural objects and localities of our planet to a world-wide extent led, on the level of UNESCO, to adoption of the Convention concerning the Protection of the World Cultural and Natural Heritage in 1972.The World Heritage List is accessible only to those states that have ratifiedthe convention and the related obligations [17], [18]. This layer will contain information about all the cultural monuments located in the territory concerned.

- Reservoirs

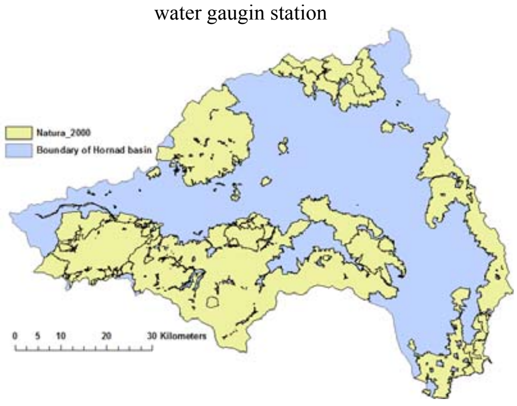
Slovakia is very rich in natural lakes, reservoirs and rivers. Reservoirs were built in order to store water to prevent flooding or to generate electricity. In the meantime, dams are also used for recreation purposes – offering water sport opportunities and accommodation facilities (www.8). This thematic layer will contain information about the most important reservoirs in the territory concerned.



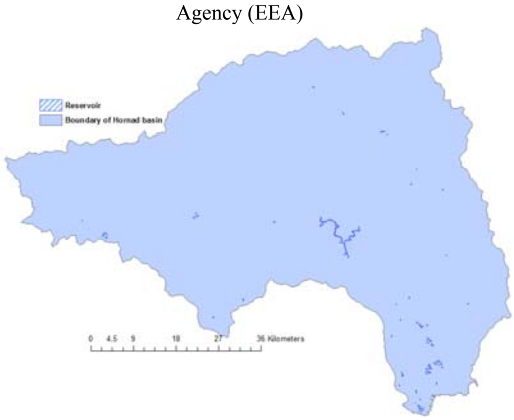
Political borders, settlements, boundary of river basin, river system, water gaugin station



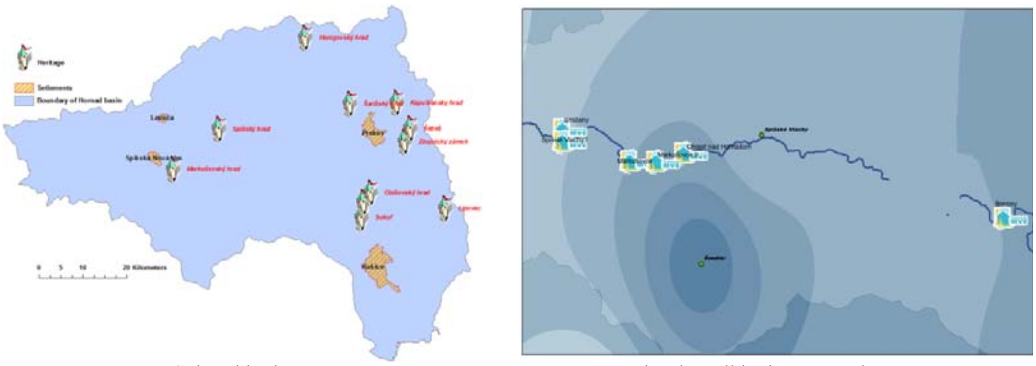
Land Use
Source: Data provided by The European Environment Agency (EEA)



Natura 2000



Reservoirs



Cultural heritage | Existed small hydropower plants

Fig. 5. The input layers in vector format.

In designing destination hydropower potential is necessary to start from the basic terms that fully affect the further use of hydropower. Since the potential of hydropower has its advantage only for systems of hydroelectric installations. In this respect, it is necessary to take into account gross hydropower potential (GP), which is defined as:

$$GP = m \, . \, g . \, h \qquad (2)$$

where: m mass of runoff, g gravitational acceleration, h elevation above sea level (from DEM) [19].

By integrating runoff time series, flow duration curves, and annual flow data in GIS based models, power and energy maps can be produced. More detailed steps are described in Figure. 8 and 9.

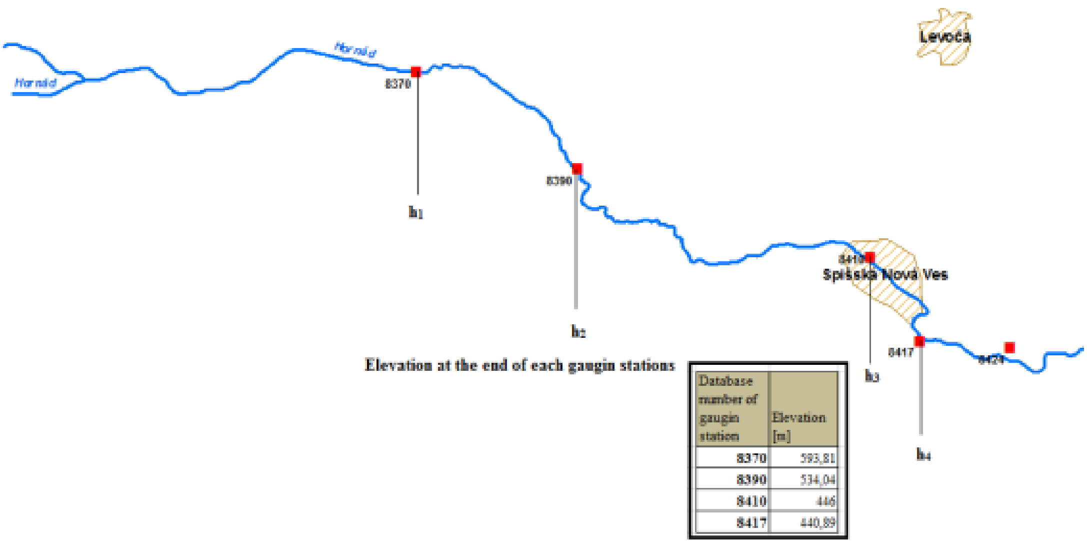


Fig. 6. Elevation at the end of gaugin stations.

Figure 6 The river split into reaches (h_1, h_2, h_3, h_4 - elevation of water level at the end of river reach). The input data: hydrographic network and DEM of river Hornád basin.

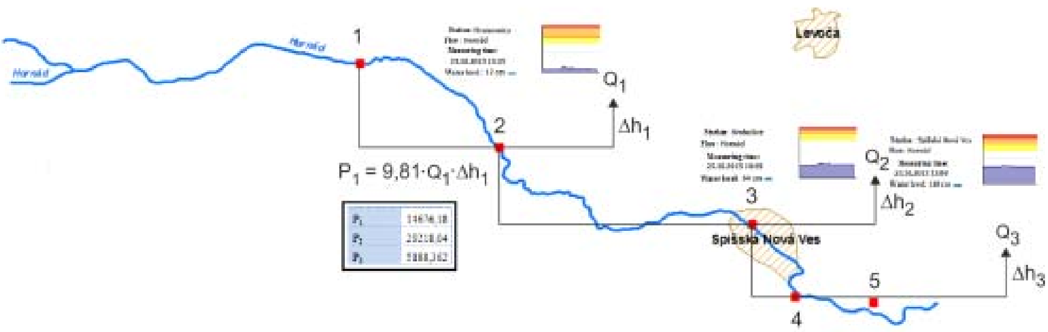


Fig. 7. Calculation of the stream power.

Figure 7 presented the calculation of monthly river flow for every segment to obtain the input data from GIS layers and calculation of hydropower potential [20].

Graphical display of the current status of the water level gauging stations is presented on Figure. 8.

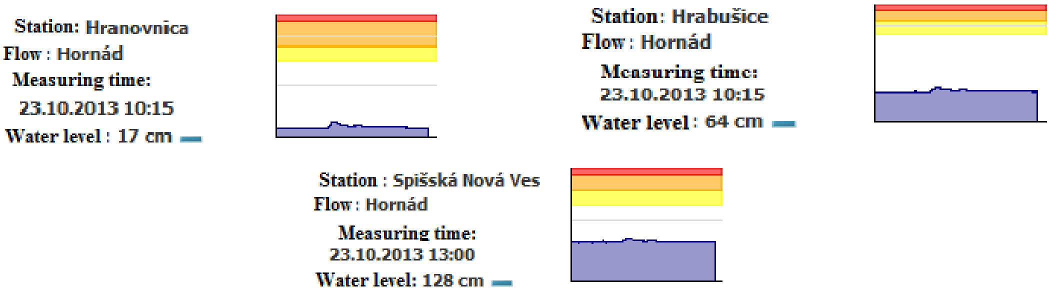


Fig. 8. Graph of water level in the water gauging stations.
Source: www.shmu.sk

Resulting calculation coefficients P1, P2, P3 process for determining the hydropower potential of the selected water stream is shown Table. 4.

Tab. 4. Calculated values of the coefficients P1, P2, P3.

P_1	14676,18
P_2	29218,04
P_3	5188,362

The Figure. 9 shows the analysis result of determining the potential of hydropower for the selected area processed according to the methodology described in the paper by Taylor and Dai [21].

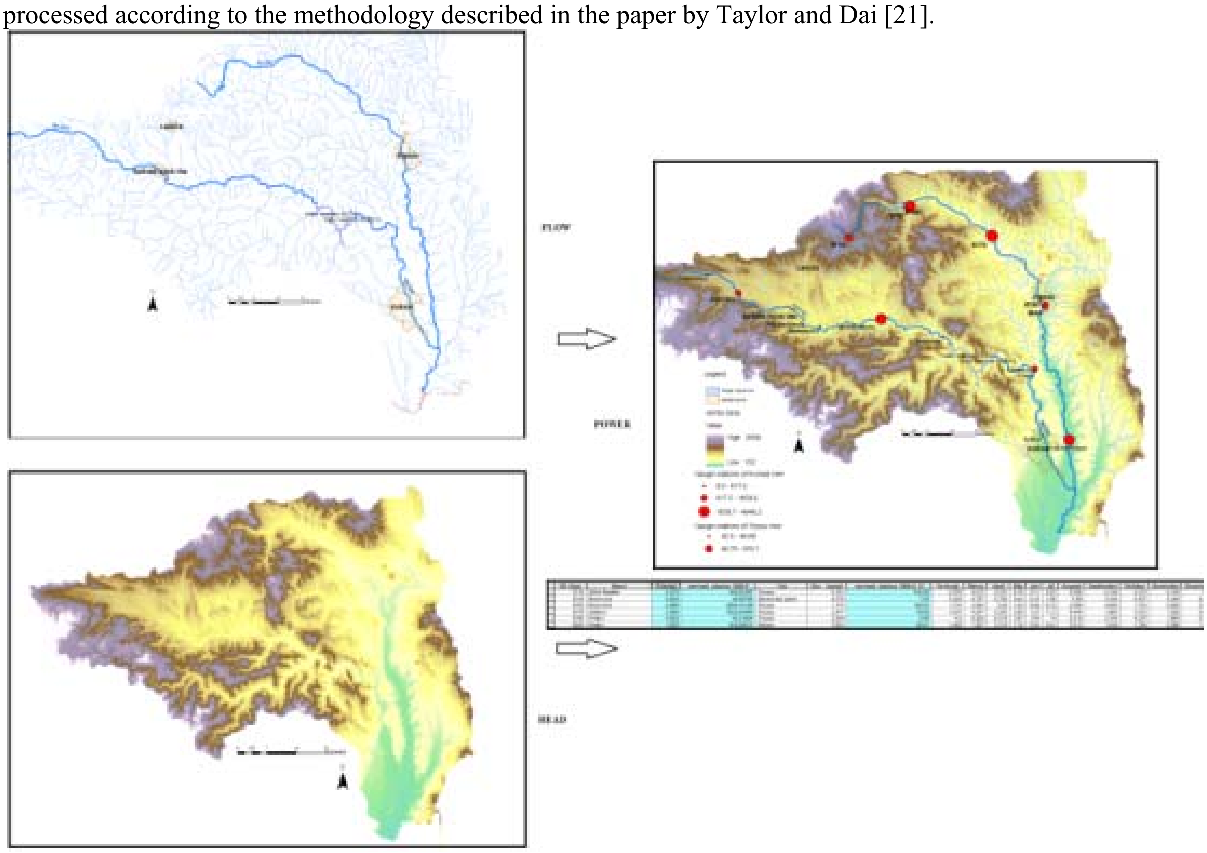


Fig. 9. Identifying potential hydroelectric sites by using GIS.

Conclusion

The aim of the article is to point at the problematic of a GIS based assessment of hydropower potential in Hornád basin. The actual processing problem of determining the potential for exploitation of hydropower require a study of available works devoted to the issue presented. Processing required a complex set of current trends in search sites for SHP. In the processing factors have been identified that directly affect the selection of sites. It was mainly flow, rainfall ratios recorded in this area, from which derive directly SHP technical parameters of functionality, such as SHP performance. Further mainstreaming was the occurrence of protected areas, height ratios presented by the terrain model, Natura 2000, UNESCO, RESERVOIRS, Landuse and many others. All terms have been taken into account processed in vector or raster representation in GIS environment. Important to have information on climatological stations of the area. Data on average monthly total precipitation for the period were selected in the GIS environment interpolated rainfall conditions. The result of interpolation offered us a usable pervasive nature of average precipitation. The main factor in determining the potential of hydropower, the calculation of gross hydropower potential of river Hornád. Through them was considered usable flow. The attention is also noted areas where there have been at least flow and rainfall conditions. On the territory of our country is also currently still much effort stakeholders seek new locations for SHP. It would be a pity, when the possibility of using increasingly high hydropower potential has been printed in the background.

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