ANALYSIS OF HYDROPWER POTENTIAL IN AN ALPINE CATCHMENT AREA WITH THE GIS TOOL VAPIDRO-ASTE

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Abstract

In the Alpine region, hydropower is the most important renewable energy source. The majority of the potential is exploited, but sustainable use of the remaining potential is important to meet the targets defined by the European Union regarding renewable power production.
One objective of the EU project "SHARE" (Sustainable Hydropower in Alpine Rivers Ecosystems) is to establish a tool to identify promising sites for hydropower plants.
Water resource assessment requires the handling of multiple forms of spatial data and therefore Geographic Information Systems (GIS) are used. The GIS-tool developed during the project is called Vapidro-Aste. Based on ESRI`s GIS software ArcGIS, it is a powerful tool for manipulating, analysing, and displaying spatial data.
The paper will discuss the GIS-based assessment of hydropower potential and the important role of GIS tools in natural resources development, using a case study in an Austrian alpine catchment area.

Keywords: GIS, hydropower potential assessment, EU project

Introduction

The assessment of the not exploited hydropower potential to increase the share of renewable electricity production is important for energy policy issues and scenarios (Europe 2020 goals). Since the utilisation of hydropower usually has a considerable impact on the body of water concerned, it is also relevant within the EU Water Framework Directive.

Even though hydropower is well developed, there are still expansion possibilities for new hydropower plants. Developing the potential of hydropower requires coordination of many varied needs, so in the study an interdisciplinary approach was adopted, integrating methods from the fields of hydraulic engineering and geography.

Alpine Space project SHARE

SHARE – Sustainable Hydropower in Alpine Rivers Ecosystems – is a running project in line with the European Territorial Cooperation Alpine Space Programme and it takes place from August 2009 to July 2012. The project is implemented by 13 partners (universities, local authorities, NGOs) from 5 different Alpine countries. Figure 1 shows the area of activity of the Alpine Space Programme and the spatial distribution of the project partners.

Figure 1: Project partnership of SHARE

Focusing on the Alpine region, the project will help to make the increasing demand for renewable energy compatible with the consideration of the environment conservation.

The project provides methodological and practical software packages to promote an integrated river management approach in the Alps. The Geographic Information System (GIS) tool Vapidro-Aste was developed in order to perform combined spatial and topological analysis of river networks to analyse the hydropower potential. For policy makers and administrations this type of analysis can assist if complex issues regarding the further development of hydropower arise.

Another software developed during the project is the decision support system SESAMO, which implements a

multicriteria approach (MCA) to assess and compare different management alternatives of hydropower plants and rivers. All the tools developed during the project have been tested and adjusted in 11 Pilot Case Studies in the 5 Alpine countries involved. Already existing information about hydropower exploitation in the Alpine area are brought together, entered into geodatabases and will be made available as web-based maps.

All software tools (Vapidro-Aste, SESAMO) will be provided at the end of the project for downloading free of charge at the homepage (http://www.share-alpinerivers.eu).

GIS in Water Resources Engineering

GIS was developed for capturing, storing, analyzing, and displaying geographically referenced data (Fürst 2004).
The use of GIS for various terrain analyzing methods is growing rapidly, also including the field of hydraulic engineering and hydrology. Various terrain characteristics for the modeling of hydrologic processes can be extracted from Digital Elevation Models (DEMs) by GIS.

GIS software tool Vapidro-Aste

The GIS-tool developed during the project is called Vapidro-Aste. Responsible for the development of the software has been RSE (Ricerca sul sistema Energetico), an Italian publicly-controlled company carrying out research in the field of electrical energy. Based on ESRI`s GIS software ArcGIS, it is a powerful tool for manipulating, analysing, and displaying spatial data. In Figure 2 the graphical user interface is shown.

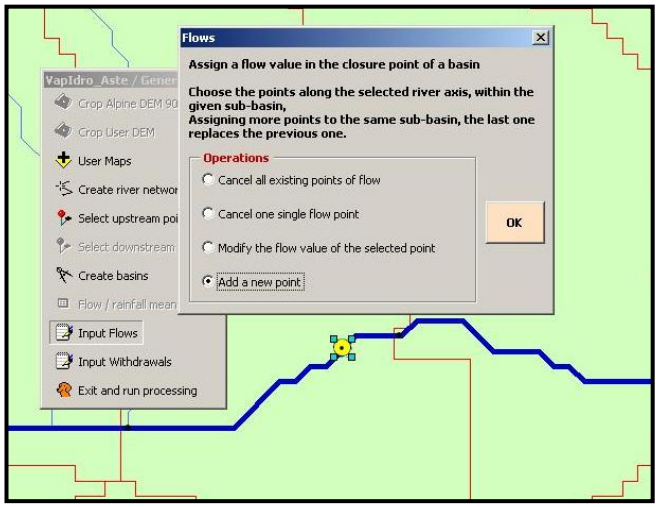

Figure 2: Graphical user interface of Vapidro-Aste

For the study presented within this paper, the software tool Vapidro-Aste was applied in its version 2.3 from July 2011. Included within the Arc GIS interface are data analyses and output visualization tools.

Generation of a synthetic river network

The main working steps performed by Vapidro-Aste for the generation of a river network are (Alterach et al. 2006):

- Cropping of the Digital Elevation Model (DEM) to a specified area
- DEM preprocessing (Fill)
- Automatic generation of a river network
- Selection of the watercourse (definition of upstream and downstream points by the user)
- Automatic generation of the sub-basins

Vapidro-Aste uses the DEM to generate a river network and it is able to split the river into multiple stream segments. It uses the ArcGIS Spatial Analyst functions to get the flow direction and flow accumulation. Cells with a high flow accumulation represent areas of concentrated flow and are used to identify the river network by means of a flow accumulation threshold set by the user. Figure 3 shows the DEM and the generated river network.

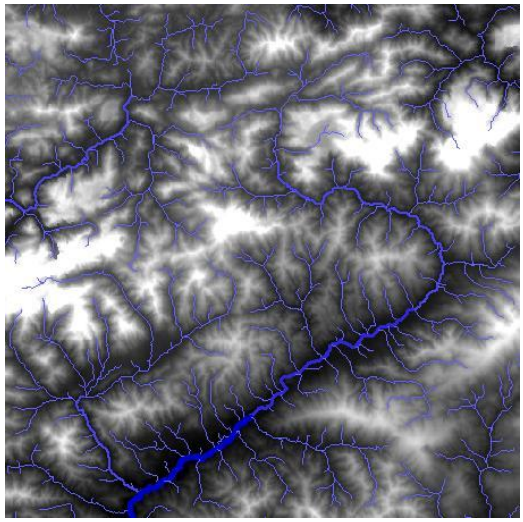

Figure 3: The generated river network in the study area

The function “basins” divides the study area into a collection of smaller sub-catchment areas, each with its own closure point. The sub basins are created automatically, with their numbers defined by the user.

Water flow

At this step of the calculation process, the user enters the measured flows in one or several points of the river stretch. To calculate the available flow for hydropower generation also human impacts are taken into account by entering water returns and withdrawals. In Figure 4 the calculation of the useable flow discharge in a given place is shown.

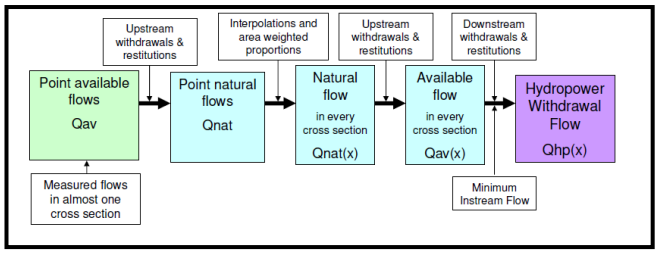

Figure 4: Schematic view of computation of the usable flow (Alterach et al. 2006)

Energy calculations

The Vapidro-Aste tool is able to calculate the gross hydropower potential (the highly theoretical potential if all runoff at all locations would be transformed into energy without any losses) as well as the technical hydropower potential (taking into account the energy losses) (Anderer 2010).

After the input of hydrological data, the user can make relevant settings for the respective area. This is done in three entry forms, with the following parameters are taken into account for the energy calculation:

- turbine efficiency
- overall efficiency of the power plant
- minimum environmental flow

The tool calculates further the hydropower potential for the selected watercourse and represents the results in a map (see the chapter results).

Optimization analysis

Furthermore, the user has the option of performing optimization analysis along an entire river stretch. The optimal hydropower exploitation of a watercourse can be simulated with this analysis function. Shown in Figure 5 is the menu, where the user can perform the analysis.

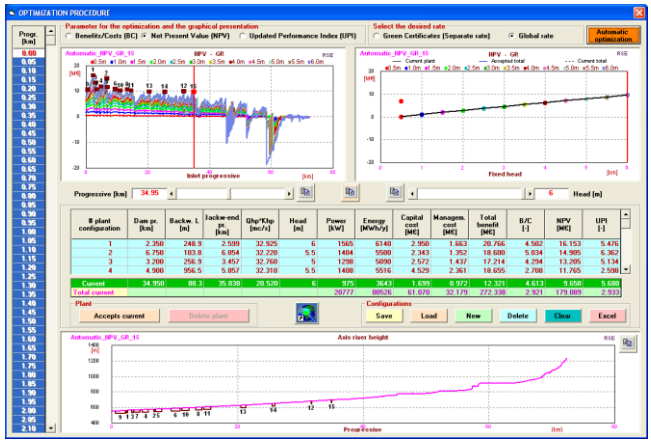

Figure 5: User menu for optimization analysis

Applicability for an Austrian alpine catchment area

The software was tested already in Italian pilot case studies (Alterach et al. 2007), but not in an Alpine catchment area like the Mürz valley. The aim was to test the software`s applicability to such an area.

The study area

The study area was selected on the basis of availability of high-resolution laser scanning images (generously provided by the Government of Styria, Geographical Information System of Styria) and is situated in the north-eastern part of the Austrian state of Styria (Figure 6).

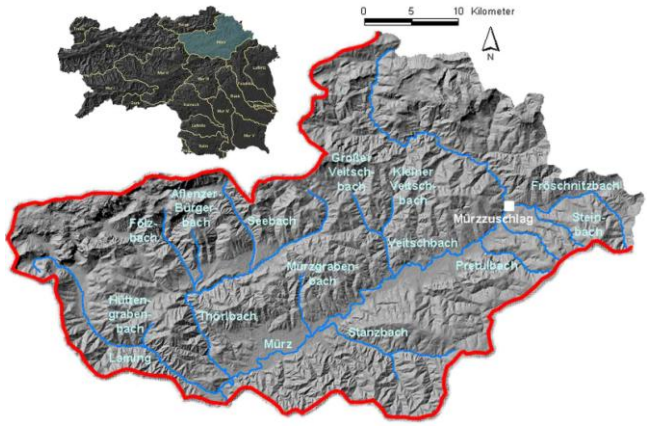

Figure 6: Map of the catchment area of the river Mürz (Wasserland Steiermark)

It covers the whole drainage area of the river Mürz and extends over approximately 1,500 square kilometers, beginning at the border to the federal state of Lower Austria at a height of 850 m above sea level to the junction with the river Mur at the city of “Bruck an der Mur” at a height of 480 m above sea level.

There are studies available for the hydropower potential of whole Austria like Schiller (1982) and PÖYRY (2008), but there are no assessments of waterpower potential solely for the river Mürz available.

Most of the hydropower resources along the river have already been developed. In order to estimate the developed hydropower potential, the installed capacities and technical features of existing hydropower plants along the river Mürz were collected in order to get the actually supplied electricity by hydropower. The result was a geo-referenced data set on existing hydropower stations.

Data acquisition

Geospatial data is information that represents the geographic location and characteristics of natural and man-made features on the surface of the Earth (Bill 1999). Regarding the input data, the most up-to-date and detailed geospatial information was made available by the federal government of Styria, one of the project partners.

Digital elevation model (DEM)

A Digital Elevation Model represents the surface and height information of a given area and is used in this study to extract certain terrain parameters. As data basis for this project altogether three DEMs with different spatial resolutions were used. On the one hand the 1x1 meters ALS laser scanner data of high resolution and quality, which the government of Styria made available, as well as a 10x10 meters DEM. A 90x90m DEM of the Alpine region, derived from the freely available SRTM data (Shuttle Radar Topography Mission) is enclosed in the program and was also used.

Hydrological data

Water discharge data were provided by the government of Styria and Vapidro-Aste calculates the available water flow for every cell by interpolation. In Figure 7 the locations of all discharge gauging stations in the study area, operated by the Hydrographic Service of Styria, are shown. The number of years of recorded data range from at least 10 to 30 years for the respective stations, the notification interval is one day.

Figure 7: Location of gauging stations in the catchment area (Google maps)

Results

The results of the tests show that Vapidro-Aste evaluates the hydropower potential of relatively large areas correctly and quickly. The tool has been proven to be useful in getting a fast overview of the hydropower potential for certain catchment areas. The generated stream segments were compared to streams in the dataset of the digital atlas of Styria and the evaluation was considered to be satisfactory.

The result for the river Mürz is shown in Figure 8 using a color range scale. The map shows identified sites in the study area with the respective hydropower potential.

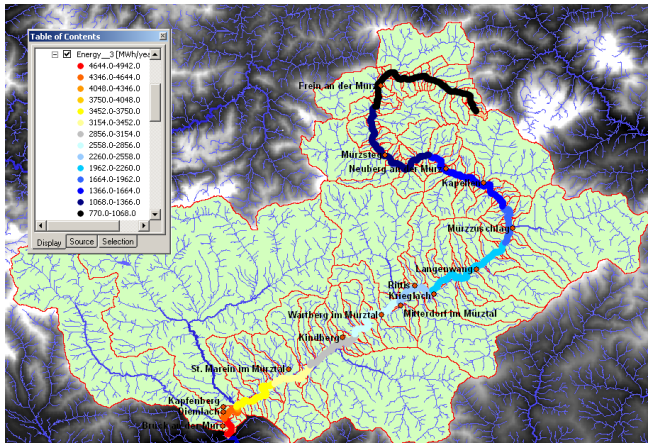

Figure 8: Map of the potential hydropower in the study area

For this study the potential of all stream segments was aggregated to determine the power potential of the whole river Mürz. The total modeled gross line potential for the entire river is approximately 330 GWh/year.

The determination of the hydropower potential was successfully validated by the comparison with sites of existing hydro power plants along the river Mürz (Schneider & Schreiber 2012). The results are shown in Figure 9. It can clearly be seen, that the location of the existing power plants (squares) corresponds to the location where the highest potential (yellow/orange) was calculated by the GIS tool.

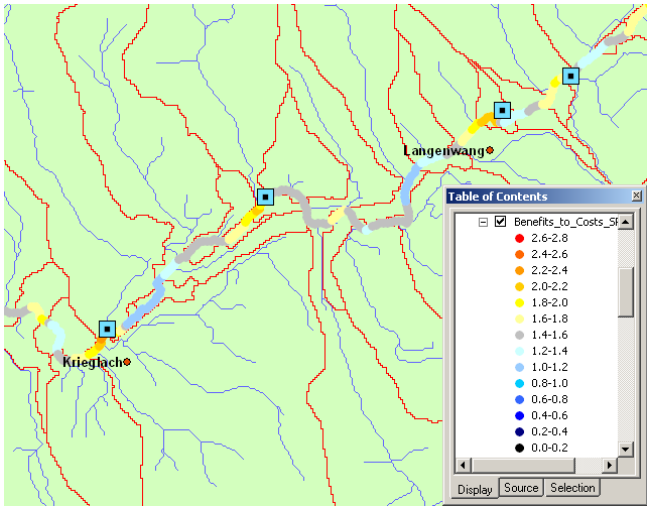

Figure 9: Validation of the results by comparison with existing hydropower plants

The financial analysis methods for hydropower plants are very complex and the methodology used in Vapidro-Aste turned out to be not unambiguously applicable for all potential hydropower sites. It will only deliver a rough assessment and more detailed studies will have to be carried out in each case to get a reliable financing plan (Heimerl 2002).

DEMs of three spatial resolutions were used in the study. It was revealed that the influence of resolution in hydrologic applications is significant. An appropriate spatial resolution, quality and precision is necessary, because if the resolution is too low the modeling of the discharge conditions will be distorted and the river network features will be reproduced inaccurately. Consequently, it must be acknowledged that the use of higher resolution DEMs increases the computation time significantly.

Conclusions

Main objective of the testing of the GIS tool Vapidro-Aste was to evaluate the capability to perform hydropower potential analysis in an Alpine catchment area.

The user friendly graphical interface within a GIS environment and the strong integration of Vapidro-Aste with the ArcGIS geo-processing environment allows users to generate their own maps easily and fast. Other relevant features such as land use or power supply systems can be displayed by simply adding other layers.
Several project partners of the SHARE program are also testing the software in their pilot case areas and their results and considerations will be used to improve the software. Since the software had not been tested before in an Austrian catchment area, calibration of the data was a very important step during this study.

Some further improvements of the software need to be made. The settings of the input masks require appropriate adjustments to the national conditions and need to be described in the manual in detail.

A test of the software`s applicability for small ungauged catchments in Alpine areas is currently carried out. The aim of the follow-up study is to investigate if the software also successfully calculates smaller river runs. Furthermore, a rainfall-runoff model (using the open-source MapWindow GIS) should be integrated in the study.

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