How Open Source GIS and Related Tools Can Help in African Project and Projects Can Help to Develop New Tools: The Case of Rwanda and the New GRASS-Epanet Interface

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Abstract

An ACP EU project is currently studying an area of north Rwanda, aimed to improve water facilities using FOSS systems. Some of the project's goals are to improve the capabilities of Rwanda water operators to design and manage water distribution networks and related resources, to built medium hydro-power plants and to carry out river restoration in order to limit river bank erosion. Rwanda has many water problems related to both water quantity and quality, therefore an effective management of the existing water systems and a correct design of the future ones are crucial to obtain sustainable results in a long term view. The project is aimed to share with the Rwanda operators the knowledge about the present water management situation and to study with them some new tools to improve the situation. These tools will include both the technical solutions regarding water system devices and the software systems to manage those system. A first interface between EPANET and GRASS GIS, two softwares useful to carry out water supply systems management and design, has been developed taking into account the results and the problems encountered in previous projects by the research group. Epanet is widely used all over the world, but all the available interfaces to and from a GIS system are proprietary. The availability of such an instrument for a FOSS GIS can be significantly useful to foster the use of this tools, allowing water managers to be more effective and to analyze a territory taking into account environmental sustainability.

1. Introduction

An ACP (water facility) European Community project is currently running in an area of north Rwanda, aimed to improve water facilities using FOSS systems. A reliable geodatabase to be used as a base for all the geographic elaboration, i.e. all the elaborations involving spatially distributed objects, is currently being developed. One of the project's goals is to setup a semi-automatic water supply systems design procedure, while improving the capabilities of Rwanda water operators to design and manage water distribution networks and related resources. Even if with some inconsistencies, Rwanda is among one of the most advanced African countries in information technology[1].

1 http://data.unaids.org/pub/Report/2008/rwanda_2008_country_progress_report_en.pdf

This capacity can be used to make the country's water supply and environmental monitoring and evaluation system function more efficiently.

Like some other African countries, Rwanda has many problems related to water, therefore an effective management of the existing water systems to control water quantity and quality, and a correct design of the future water supply systems are crucial to obtain sustainable results in a long term view in a fragile environment. The project will use a cooperative approach, sharing with the Rwanda operators the knowledge about the present water management situation and studying with them some new tools to improve the situation. These tools will include both the technical solutions regarding water system devices and the software to manage those systems.

The management of the systems can be improved by means of tools like Epanet, a public domain software dedicated to water supply systems management and design, but they can be further improved by coupling this tool with a GIS. The Epanet software is public domain and it is widely used all over the world,, but no FOSS interface is available to exchange data to and from a GIS system, although MS windows only, freeware applications such as epa2gis and shp2epa are available.

Therefore, an interface between the FOSS GIS GRASS and Epanet is currently under development with a preliminary version presented here. The process that has brought the group to develop such a tool is tightly tied to other African projects carried out in Mozambique, Tanzania and Rwanda. In our experience, the separate use of Epanet and GRASS has been very useful to manage difficult situations and to prevent the risk of water quality decay. The problem is that data flow between the two softwares is not so intuitive, thus creating unnecessary complications for the operators. Users find difficult the transformation of data coming from GIS to Epanet and vice-versa, so they use data in the two separate environments, losing a lot of possibilities and doubling the work and the checks necessary to test correspondence between data stored in both softwares. The need of an interface that makes the two software easily "talk" is evident. The availability of such an instrument for a FOSS GIS can be significantly useful to spread the use of this tools, allowing water managers to be more effective. Nowadays, an effective design of a water supply system must take into account not only technical problems that can be solved by means of personal experience and with software skills, but also sustainability aspects that can be highlighted by the use of a GIS.

2. GRASS and EPANET

GRASS is one of the most important FOSS GIS (http://grass.osgeo.org/), has a long history and has been used widely all over the world in many different projects and applications (http://grass.osgeo.org/applications/index.php, Ciolli & Zatelli 2005). Due to its completeness and adaptability, GRASS can be considered the most advanced FOSS GIS and the FOSS license makes it the ideal tool to spread GIS technology in developing countries (Bezzi et al. 2006, Ciolli et al 2006).

EPANET is a Software that models the hydraulic and water quality behavior of water distribution piping systems created by United States Environmental Protection Agency (http://www.epa.gov/nrmrl/wswrd/dw/epanet.html) and can be used to design and manage water supply systems. Epanet tracks the flow of water in each pipe, the pressure at each node, the height of the water in each tank, and the concentration of a chemical species throughout the network during a simulation period. Epanet is a public domain software widely used both in Universities for research and teaching purposes (Ostfeld and Tubaltzev 2008, Marunga et al. 2006, Hernandez-Castro 2007, Sakarya and Mays 2000, Ratnayake and Jayatilake 1999) and in the professional world as a tool to design effective water supply systems.

2.1 Aims of the Integration Between the Software Systems

A first step toward a complete integration has been the development of the possibility to exchange data between the two software systems, preserving cartographic coordinates and attributes when data are passed from GRASS to Epanet and water system information when data are passed from Epanet to GRASS.

In this way, the water supply network can be designed taking advantage of the geographic data and functions available in GRASS, while hydraulic parameters evaluated by Epanet are available in the geographic database and can be stored in a generic geodatabase. The advantages coming from the use of Epanet data in a GIS are tied to the significant analysis possibilities that a GIS can offer: geostatistics, satellite and aerial photograph image analysis, digital elevation model analysis and creation. The use of GIS data in EPANET allows to deploy in a GIS environment the significant analysis possibilities that EPANET offers regarding water supply systems.

Moreover, previous experiences in African projects have shown that when data transfer among different platforms becomes too complicated, users tend to replicate database in each platform leading to inconsistencies, data fault or loss and, eventually, to data quality degradation. The same experiences have shown that when users are allowed to use both GIS and EPANET using reliable data, they obtain the best from the two environments.

2.2 The Interface

A first working simple interface has been developed and it will be soon under a testing phase within a selected group of Rwanda operators. The interface allows the possibility to transfer data to and from both softwares, without losing information. The water supply system can be designed on a map using GRASS tools, taking into account digital elevation models, contour lines, satellite and aerial images, GPS data and other topographic information, and using Geographic coordinates defined in a cartographic reference system. The result can be translated into EPANET and analyzed using the proper tools. Results of the elaboration can be easily re-imported into GRASS. The operation can be performed also in the reverse direction, with the network design carried out in EPANET.

Figure 1. First interface to translate data from GRASS to EPANET

The interface has been developed studying EPANET input/output files format detail, to design a geodatabase carrying the same information, both geographic and semantic. Once data are available in a geodatabase format, like PostGIS/PostgreSQL, data can be accessed by means of any GIS able to read it, proprietary and FOSS. While water supply systems design and management can be carried out effectively with EPANET, GRASS can be used to map existing (or possible) erosion risk areas, river restored areas (naturalistic engineering), hydro-power plants, agriculture and grazing land use and all these information can contribute to model the response of the territory to future impact.

The research group is currently carrying out tests to verify the translation tool.

3. FOSS GIS and Sustainability

A further important goal of the project is to foster the adoption of FOSS GIS and related software for land planning and natural resource management, operating a transition from proprietary software to FOSS. For this reason, in the next months and years (the duration of the project is three years) the interface will be perfected and courses will be held both to share knowledge about generic GRASS use and to teach specifically how to manage water systems with running EPANET within GRASS. The courses will be held by means of specifically developed tutorials, using local examples and in French language. The project is addressed not only to water technicians and software specialists, but also to local communities.

The project goes beyond the mere technical applications and involves also the local communities to maintain riversides with simple natural techniques and to learn together how to carry out a sustainable use of water in order to protect the fragile and already dramatically altered ecosystems of the overpopulated area. River and water management is particularly delicate (Shiva 2002, Nilsson 2007, Zhou et al. 2008) because involves not only water quality and availability (Richardson et al. 2007, Lawson et al. 2007), but also the persistence of local ecological conditions which allow agricultural techniques and grazing (Diamond 2006, Shiva 2002). Moreover, riparian and natural environment restoration can also have a significant monetary value (Blignaut & Moolman 2006, Ojeda et al. 2008).

Mapping river restoration can be especially useful to monitor its evolution in the future. River restoration (carried out with techniques that try to mimic natural environment behavior) uses local native plant species; the experience and cooperation of native people are fundamental to obtain good results.

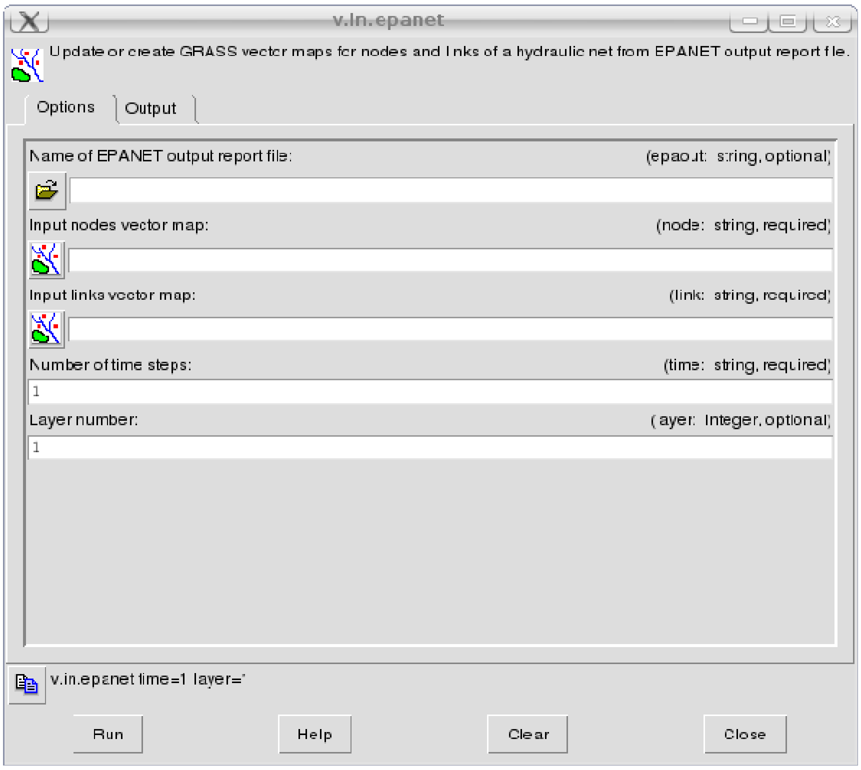

Figure 2. Prototype interface for data flow from EPANET to GRASS

However, even with the best collaborative effort between local and foreign technicians, the perfect restoration interventions and the participation of local communities, a continuous and correct monitoring will be needed both on the field and keeping track of land changes to guide the process correction that will be necessary in the long term, with an iterative self correcting process.

The adoption of naturalistic engineering techniques is taken into account to reduce the impact of new medium-micro hydro-power plants which are being set up during the project and the solution of the overgrazing problem or agricultural over-exploiting of river banks. Past tragic events occurred in Rwanda (Diamond 2006) are the clear indicators that only a sustainable approach in the area can give some hope that people will have enough to maintain themselves and live in peace in such an over populated area. Management and planning must be carried out involving the society at all levels, and communities participation is crucial to try to have long terms results both in software knowledge spreading and in simple land management techniques application.

In this environment the use of FOSS GIS is particularly important because guarantees freedom to use software and independence.

4. Conclusions

Different previous experiences carried out in Africa have driven the group to develop a GRASS–EPANET interface. GRASS EPANET interface is a first step forward to integrate a software specifically designed for water supply system management with a FOSS GIS, giving advantages both to GRASS and to EPANET.

As in the tradition of FOSS the interface can be improved and expanded hopefully not only by the authors, but also by everyone who is interested in its development.

Future monitoring will be crucial for the whole project and a geographical approach together with local communities participation can be the tools to succeed in the monitoring and the preservation of riparian restoration, water resources, natural environment and agricultural and grazing land. The new created interface could be important to make easier the work of technicians, but the overall project success depends on the participative approach. Tools alone do not guarantee nor project results, neither quality.

Certainly, the possibility to deal with GIS and water supply system with an integrated approach can be useful both to spread GIS technologies and FOSS systems.

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