THE H2020 FREEWAT PROJECT FOR DEVELOPING A GIS-INTEGRATED PLATFORM FOR WATER RESOURCE MANAGEMENT

Giovanna De Filippis [1], Iacopo Borsi [2], Laura Foglia [3], Massimiliano Cannata [4], Violeta Velasco Mansilla [5], & Rudy Rossetto [1]

(1) Istituto di Scienze della Vita, Scuola Superiore Sant'Anna, Pisa (Italy); (2) TEA SISTEMI S.p.A., Pisa (Italy); (3) Institut für Angewandte Geowissenschaften, Technische Universität Darmstadt, Darmstadt (Germany); (4) Istituto di Scienze della Terra, Scuola universitaria professionale della Svizzera italiana, Canobbio (Switzerland); (5) Instituto de Diagnóstico Ambiental y Estudios del Agua, Consejo Superior de Investigaciones Científicas, Barcelona (Spain)

KEY POINTS:

- *Sustainable management of ground- and surface-water resources can be supported by numerical models to increase understanding of complex natural systems and improve planning strategies*
- *Integrating GIS and hydrological codes may enhance the use of complex modeling environments, allowing to store and to manage large spatial datasets and model pre- and post-processing*
- *FREEWAT is an open source and public domain, QGIS-integrated platform, developed to simulate several hydrological processes in order to address decision making in water resource management*

1 INTRODUCTION

Due to intense exploitation, degradation of accessible ground- and surface-water resources has become a severe issue in terms of both quantity and quality. Because of growing human pressure and climate changes, addressing proper management and planning strategies is critical to restore unbalanced situations and/or prevent future scenarios of degradation.

Numerical models are thought to be relevant to address the above mentioned issues, as highlighted by regulations and recommendations of the EU and the European and Environment Agency, stressing on the importance of developing innovative software tools to address water management issues (EU, 2000).

These tools may provide a thorough representation of hydrological systems and related processes, thus providing a full characterization of the involved flow terms and contaminant transport pathways. However, despite the need to perform such tasks, simulation tools for integrated water management are still scarce (Rossetto et al., 2013).

The EU HORIZON 2020 FREEWAT project (*FREE and open source software tools for WATer resource management*; Rossetto et al., 2015) aims at simplifying the application of EU water-related Directives providing an open-source and public-domain, GIS-integrated solution for planning and management of surface- and ground-water resources. This will facilitate the widespread use of complex modeling environments, taking advantage of storing, managing and visualizing large spatial datasets. FREEWAT expected main impact is helping in producing scientifically and technically sounding decision and policy making based on:

- data and innovative data analysis tools, and
- including participatory approach not only in the final stage of discussion, but also during the phase of scenario generation.

2 MATERIALS AND METHODS

Through creating a common environment among water research/professionals, policy makers and implementers, FREEWAT main impact will be on enhancing science and participatory approach and evidence-based decision making in water resource management, hence producing relevant and appropriate outcomes for policy implementation.

In this framework, the FREEWAT platform, developed within the open source QGIS GIS (QGIS Development Team, 2009), allows the simulation of the whole hydrological cycle and the analysis of several

water data. Input and output data are managed through a SpatiaLite Data Base Management System (DBMS).

The FREEWAT hydrological model is based on fully distributed and physically-based numerical codes, mainly from the open source USGS MODFLOW family (Regione Toscana, 2014). In particular, it integrates one of the latest and most complete version, to date, of MODFLOW, namely MODFLOW-OWHM (One-Water Hydrologic Flow Model; Hanson et al., 2014). FREEWAT capabilities include:

- solute transport in groundwater flow systems and in the unsaturated zone;
- tools for the analysis, interpretation and visualization of hydrogeological data;
- tools for dealing with groundwater quality issues through analysis of hydrochemical data;
- time-series processing to support advanced model calibration;
- a whole module for sensitivity analysis, calibration and parameter estimation;
- a dedicated module for water management and planning, with particular focus on rural environments.

As such, the FREEWAT platform is conceived as a canvas, where several simulation codes, based on the hydrological cycle, hydrochemical or economic-social processes, might be virtually integrated.

The main advantage of using the FREEWAT platform is the integration of a whole simulation environment in a unique GIS desktop, coupling the power of GIS geo-processing and post-processing tools in spatial data analysis to that of simulation software. Such integration allows to consider both the spatial and the time variability of the various hydrological factors, in order to enhance modelling and water management capabilities from a technical point of view and to support water policies implementation and decision making applications. Coupling is guaranteed in FREEWAT through a tight coupling approach, where GIS and hydrological model engines work separately, but the first provides the interface where data are pre-processed, run and then visualized. Availability of GIS-integrated simulation environments allows to definitely make easy model setting-up and to avoid data isolation, data integrity problems and broken data flows between models and the pre- and post- processing environment.

A spatial database was designed using SpatiaLite DBMS to store and handle geographical and alphanumerical data needed for the simulation of a hydrological model. Information stored in such DBMS is managed in the framework of a Unified Modeling Language scheme, by means of Model Data Objects (MDOs) containing spatial, temporal and finite difference grid data and created from a geographical input (a point, line or polygon GIS layer), a temporal input (derived from a timetable) and a finite difference grid. MDOs are needed to generate inputs for codes simulating specific processes.

Besides introducing a new software solution, a further goal of the project is to design a framework able to help hydrologists, GIS experts and planners in defining and simulating scenarios, visualizing results and carrying on post-processing analysis in an unique modelling environment. For this scope, a thorough set of modeling and processing tools is available to set up model geometry (both in the horizontal and vertical planes), define time discretization for the simulated processes, assign model properties and specific boundary conditions and source/sink terms, run the model and visualize results, as well as to activate auxiliary tools for data analysis and evaluation of model reliability (figure 1).

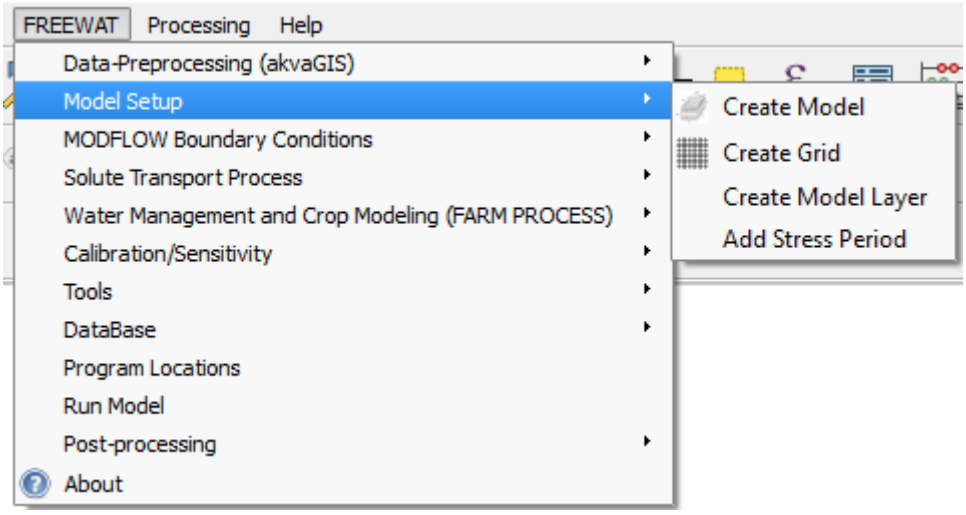

Figure 1. Screenshot of the FREEWAT plugin main window, showing the Model Setup tool expanded.

3 CONCLUSIONS

The FREEWAT platform is conceived especially for water authorities and public/private companies to build a high informative and dynamically growing representation of hydrologic systems where performing data storage and planning analysis. The FREEWAT exploitation will highly depend on its testing phase and on widespread training activities. Within the FREEWAT project, about 900 technicians throughout EU, Switzerland, Turkey, Ukraine and Africa (with the cooperation of UNESCO-IHP) will be trained. Fourteen case studies will be set up to demonstrate the full platform capabilities at different scales. Nine case studies (8 in EU plus 1 in Switzerland) will be devoted to the application of the FREEWAT platform to the Water Framework Directive and Groundwater Directive; five case studies (2 in EUs, 1 in Turkey, 1 in Ukraine, and 1 in Africa, through UNESCO involvement) will be devoted to rural water management. As the platform is free and open, contributions to further development by research institutions, private developers etc. are welcome, in the view of an initiative "*ad includendum*". The software suite is complemented by user manuals and training material.

ACKNOWLEDGEMENTS

This paper is presented within the framework of the project FREEWAT, which has received funding from the European Union's HORIZON 2020 research and innovation programme under Grant Agreement n. 642224.

4 REFERENCES

EU, Directive 2000/60/EC of the European Parliament and of the Council establishing a framework for the Community action in the field of water policy, Official Journal (OJ L 327) on 22 December 2000.

Hanson, R.T., Boyce, S.E., Schmid, W., Hughes, J.D., Mehl, S.M., Leake, S.A., Maddock, T. & Niswonger, R.G. One-Water Hydrologic Flow Model (MODFLOW-OWHM), 2014, U.S. Geological Survey, Reston, Virginia.

QGIS Development Team, QGIS Geographic Information System. Open Source Geospatial Foundation Project, 2009. http://qgis.osgeo.org [Accessed 11/03/2016]

Regione Toscana. Evoluzione del sistema open source SID&GRID di elaborazione dei dati geografici vettoriali e raster per il porting negli ambienti QGis e Spatialite in uso presso la Regione Toscana - CIG: ZA50E4058A, 2014, language: Italian.

Rossetto, R., Borsi, I., Schifani, C., Bonari, E., Mogorovich, P. & Primicerio, M. SID&GRID: integrating hydrological modeling in GIS environment, Rendiconti Online Società Geologica Italiana, 2013, 24, 282-283.

Rossetto, R., Borsi, I. & Foglia, L. FREEWAT: FREE and open source software tools for WATer resource management, Rendiconti Online Società Geologica Italiana, 2015, 35, 252-255.