Evaluating conjunctive use of ground- and surface-water and crop yield in rural environments by means of simulation tools

Giovanna De Filippis[1], Federico Triana[1], Matteo Ghetta[1], Iacopo Borsi[2], Wolfgang Schmid[3], Rudy Rossetto[1]*

[1] Scuola Superiore S. Anna – Istituto di Scienze per la Vita, Pisa, Italy.
**Corresponding email: g.defilippis@santannapisa.it*

[2] TEA Sistemi S.p.A., Pisa, Italy

[3] Commonwealth Scientific and Industrial Research Organisation, Perth, Australia

ABSTRACT

During the last decades, attention is being payed to Water Resource Management (WRM), especially due to the growing pressure related to overexploitation and climate change. This holds especially true in rural areas, where the bulk of water consumption occurs. As such, conjunctive use of ground- and surface-water is being increasingly adopted worldwide to enhance crop production sustainability, while managing the use of water resources. In this framework, ICT (Information and Communication Technology) tools, such as modelling engines integrated in GIS environments, may allow water managers to estimate the effects of natural and anthropic impacts on groundwater resource and to properly manage water use for agricultural purposes.

Within the H2020 FREEWAT (FREE and open source software tool for WATer resource management) project, this topic has been taken into account, as rural WRM was considered a major priority by the involved stakeholders.

Keywords: conjunctive use, crop yield, FREEWAT, Farm Process, Crop Growth Module

METHODS

The FREEWAT project aimed at promoting and simplifying the application of EU water-related directives through the application of a free and open source, GIS-integrated platform for the simulation of several processes involved in the hydrologic cycle (i.e., groundwater dynamics, interaction with surface water bodies, solute transport processes, conjunctive use of ground- and surface-water, etc.).

Among the others, the FREEWAT platform integrates modelling tools to deal with conjunctive use of ground- and surface-water in rural areas. To this aim, the Farm Process (FMP), embedded in MODFLOW-OWHM (MODFLOW One-Water Hydrologic Flow Model; Hanson et al., 2014), was integrated within the FREEWAT platform. FMP calculates supply-and-demand components of the irrigated agriculture on a farm scale (including head-dependent inflows and outflows, such as canal losses and gains, surface runoff, surface-water return flows, evaporation, transpiration, and deep percolation of excess water), and integrates such components within the hydrological budget calculated by MODFLOW-2005 (Harbaugh, 2005).

Within the FREEWAT platform, FMP was also coupled to a module, the Crop Growth Module (CGM), for the simulation of the crop growth cycle. CGM is a radiation-based model belonging to the EPIC family models (Williams et al., 1989), which estimates crop yield at farm and basin scale, under different climatic and water supply constraints. Specifically, CGM exploits FMP results related to water availability in the unsaturated zone, and crop water demand and water uptake, by taking also into account how weather affects the crop growth cycle.

RESULTS

The FMP-CGM approach is demonstrated by a simple synthetic application, where the growth cycle of irrigated sunflower in a Mediterranean area was simulated between 1st April and 31st August 2017. Model results show that crop irrigation demand is satisfied by natural uptake and surface water resources up to the end of May, while a supplementary source of water (provided by groundwater wells) is needed during the summer season, due to poor surface water availability and increased evapotranspiration demand. The following supply-and-demand components were quantified: rainfall recharge, irrigation provided via ground- and surface-water resources, direct uptake from the capillary zone, runoff, water percolation to the aquifer, evaporation from irrigation and from groundwater, transpiration from irrigation, from groundwater, and from precipitation. Sunflower yield at harvest was thus inferred.

CONCLUSIONS

The approach presented in this contribution aims at providing water authorities and public/private companies with a dynamic tool for agricultural water management. In this framework, the proposed approach aims at supporting the design of efficient irrigation schemes able to manage conjunctive use of ground- and surface-water, thus reducing unplanned use of private irrigation wells. Also, the efforts spent to design this approach aims at boosting digitalization in the agricultural water sector for improving WRM.

Acknowledgements

This paper provides exploitation of the H2020 FREEWAT project results. The FREEWAT project received funding from the European Union's HORIZON 2020 research and innovation programme under Grant Agreement n. 642224.

References

Hanson R.T., Boyce S.E., Schmid W., Hughes J.D., Mehl S.M., Leake S.A., Maddock T., Niswonger R.G., 2014. One-Water Hydrologic Flow Model (MODFLOW-OWHM). U.S. Geological Survey, Techniques and Methods 6-A51, 134 pp.

Harbaugh A.W., 2005. MODFLOW-2005, The U.S. Geological Survey Modular Ground-Water Model - the Ground-Water Flow Process. U.S. Geological Survey, Techniques and Methods 6-A16, 253 pp.

Williams J.R., Jones C.A., Kiniry J.R., Spanel D.A., 1989. The epic crop growth-model. Trans. Asae 32, 497–511.