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The ESPAT tool: a general-purpose DSS shell for solving stochastic optimization problems in complex river-aquifer systems

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Stochastic programming methods are better suited to deal with the inherent uncertainty of inflow time series in water resource management. However, one of the most important hurdles in their use in practical implementations is the lack of generalized Decision Support System (DSS) shells, usually based on a deterministic approach.

The purpose of this contribution is to present a general-purpose DSS shell, named Explicit Stochastic Programming Advanced Tool (ESPAT), able to build and solve stochastic programming problems for most water resource systems. It implements a hydro-economic approach, optimizing the total system benefits as the sum of the benefits obtained by each user. It has been coded using GAMS, and implements a Microsoft Excel interface with a GAMS-Excel link that allows the user to introduce the required data and recover the results. Therefore, no GAMS skills are required to run the program.

The tool is divided into four modules according to its capabilities: 1) the ESPAT_R module, which performs stochastic optimization procedures in surface water systems using a Stochastic Dual Dynamic Programming (SDDP) approach; 2) the ESPAT_RA module, which optimizes coupled surface-groundwater systems using a modified SDDP approach; 3) the ESPAT_SDP module, capable of performing stochastic optimization procedures in small-size surface systems using a standard SDP approach; and 4) the ESPAT_DET module, which implements a deterministic programming procedure using non-linear programming, able to solve deterministic optimization problems in complex surface-groundwater river basins.

The case study of the Mijares river basin (Spain) is used to illustrate the method. It consists in two reservoirs in series, one aquifer and four agricultural demand sites currently managed using historical (XIV century) rights, which give priority to the most traditional irrigation district over the XX century agricultural developments. Its size makes it possible to use either the SDP or the SDDP methods. The independent use of surface and groundwater can be examined with and without the aquifer. The ESPAT_DET, ESPAT_R and ESPAT_SDP modules were executed for the surface system, while the ESPAT_RA and the ESPAT_DET modules were run for the surface-groundwater system. The surface system's results show a similar performance between the ESPAT_SDP and ESPAT_R modules, with outperform the one showed by the current policies besides being outperformed by the ESPAT_DET results, which have the advantage of the perfect foresight. The surface-groundwater system's results show a robust situation in which the differences between the module's results and the current policies are lower due the use of pumped groundwater in the XX century crops when surface water is scarce. The results are realistic, with the deterministic optimization outperforming the stochastic one, which at the same time outperforms the current policies; showing that the tool is able to stochastically optimize river-aquifer water resources systems. We are currently working in the application of these tools in the analysis of changes in systems' operation under global change conditions.

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