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Partial validation of a socio-economic system dynamics model against a process based hydro-geological model

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We develop a high order, multi-loop nonlinear (system dynamics) model for socio-economic sustainability assessment of groundwater resources. Structure and behavior validation of dynamic system models as such pose several challenges. While some of these challenges stem from the ambiguities in theoretical representations of multi-sectorial systems, others stem from the lack of sufficient time varying data sets to calibrate the model reference behavior. In this paper, we focus on partial validation of the groundwater component of this multi-sectorial model. For this purpose, we test the behavioral response of the system dynamics model against a process-based surface/subsurface hydrogeological model. For testing purposes, the hydrogeological model is regarded as the best representation of the reality (a synthetic reality), concerning groundwater flows and accumulations. The system dynamics model is built on Stella Architect and runs on annual time steps for a time horizon of 20 years. The embedded groundwater is a non-spatial, one compartment representation -a box model- of the saturated zone, changing with lateral flows, vertical recharge and anthropogenic extractions. The hydrogeological model is built on the UFZ1-MODFLOW computer program. It simulates evapotranspiration and one-dimensional vertical flow through the vadose zone, and horizontal flow through the underlying aquifer system. The model was developed based on available borehole and pumping tests data and calibrated using observed transient groundwater level data. While the box model and the hydrogeological model are different structural entities, the spatially aggregated behavioral response of the latter under specific experimental conditions help structural validation and calibration of the box model. For this purpose, we apply multiple tests on the lateral and vertical recharge of the hydrogeological model under constant boundary hydraulic head, precipitation, irrigation and evapotranspiration conditions to observe the response in spatially aggregated hydraulic head. We repeat the same experiments on the box model, first to confirm the equations used to simulate the aggregated hydraulic flows, and to estimate the two parameters, “aquifer bottom” and “fractional evaporation” for calibration of the spatially aggregated hydraulic head. The testing process is very useful to arrive at a reliable water budget and hydraulic head response in the system dynamics model, which is going to serve for socio-economic sustainability analysis under stakeholder participation.

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