Review accessible integration of agriculture, groundwater, and economic models using the Open Modeling Interface (OpenMI): methodology and initial results

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This paper presents an interesting and valuable discussion about some of the technical key issues when trying to couple models developed in different disciplines. In this case, three models from three different domains were hooked up: a hydrological groundwater model, an agronomic crop model, and an economic crop choice model. Not only the application domains and programming languages differ, also the intrinsic nature of the models. For instance, the groundwater model is a simulation model, whereas the economic model is a statistical choice probability model. The authors succeed in accurately describing the practical issues involved when applying existing models in a modular framework, in particular the identification of linkable individual components (input and output data), temporal and spatial scale and the main focus of the paper: the software needed to facilitate the data exchange between model components in the Open Modeling Interface. Given the focus of the paper on model integration, existing models are fully re-used, that is, model source codes are left unchanged. One of the paper's main contributions to the existing empirical literature is perhaps the transparent presentation of the integrated model calibration. Calibration results for the integrated model are compared with the calibration results for the three individual model components in a rare effort to provide both analysts and policymaker better insight into the validity and reliability of the integration procedure.

On the downside perhaps, a number of issues struck whilst reading the paper. First, there is little evidence of historical memory given the fact that water use in irrigated agriculture has been the prime focus of many of these integrated models, going back to the 1960s when resource economists developed the first optimal control (demand management) groundwater models for irrigated agriculture (e.g. Burt, 1964, 1966). The European Water Framework Directive (WFD) requires an economic analysis, but not necessarily an integrated policy model, although integrated modeling is expected to become an increasingly important information tool to support policy and decision-making in the WFD (Brouwer and Hofkes, 2008; Brouwer and de Blois, 2008).

Second, the economic model is not really a standard economic model in the classical sense. It is a statistical model that allows calculation of crop choice shares given specific values for the independent variables, not an economic optimization model minimizing production costs and/or maximizing yield benefits to achieve an economically efficient (optimal) solution in groundwater resource allocation decisions. In practice, hydrological simulation models are usually coupled to economic optimization models. This is not the case in the study presented here. The results from the policy scenario analysis are as expected: groundwater use goes down as its use is regulated or incentivized (restricted in both cases). However, whether these scenarios represent the economically most efficient solutions is unclear. An important advantage of economic optimization is that the policy or decision-maker is given information about the least cost way to reach environmental objectives or about maximum crop yields respecting environmental objectives, in this case related to groundwater recharge rates to avoid overexploitation.

It is also not clear from the paper what role crop prices play in the modeling approach. From an economic point of view, the trade-off in the decision-making process is between pumping costs and crop yields and the relevant question is at which point marginal (pumping) costs equal marginal benefits (crop prices). The presented economic model seems to be driven ('triggered') primarily by the availability of water (water level change), not crop prices and net benefits (e.g. where pumping costs presumably go up as a result of decreasing water levels or opportunity costs of groundwater well depletion etc).

A third and final issue that puzzled me a bit was the role of rainfall and variations herein on the water stock at the beginning and end of each simulated time period over the 15 year time horizon due for example to climate change. The model clearly is dynamic, but the issue of stock replenishment in the simulation process remained a bit unclear to me, and related to that - and despite the extensive discussion of model calibration - perhaps the issue of uncertainty, for instance related to the unpredictability of weather conditions, but also model parameters remained slightly underexposed. Not having full insight in trends in precipitation patterns, and as a result water scarcity and the shadow price of water, makes it harder to understand what triggers the 'decision' for crop choices and final model output: water scarcity, changes in crop prices, pumping costs or other input factors. An interesting extension of the model would have been to estimate groundwater shadow prices. However, this is only possible if an economic optimization model would have been used.

References

Brouwer, R. and Hofkes, M. (2008). Integrated hydro-economic modelling: Approaches, key issues and future research directions. Ecological Economics, 66(1), 16-22.

Brouwer, R. and De Blois, C. (2008). Integrated modelling of risk and uncertainty underlying the selection of cost-effective water quality measures. Environmental Modelling & Software, 23, 922-937.

Burt, O. R. (1964). Optimal resource use over time with an application to groundwater. Management Science 11: 80–93.

Burt, O. R. (1966). Economic control of ground water reserves. Journal of Farm Economics 48: 632–647.