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Multiobjective optimization for Groundwater Nitrate Pollution Control. Application to El Salobral-Los Llanos aquifer (Spain).

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Water quality management is complex due to the inter-relations between socio-political, environmental and economic constraints and objectives. In order to choose an appropriate policy to reduce nitrate pollution in groundwater it is necessary to consider different objectives, often in conflict. In this paper, a hydro-economic modeling framework, based on a non-linear optimization(CONOPT) technique, which embeds simulation of groundwater mass transport through concentration response matrices, is used to study optimal policies for groundwater nitrate pollution control under different objectives and constraints. Three objectives were considered: recovery time (for meeting the environmental standards, as required by the EU Water Framework Directive and Groundwater Directive), maximum nitrate concentration in groundwater, and net benefits in agriculture. Another criterion was added: the reliability of meeting the nitrate concentration standards. The approach allows deriving the trade-offs between the reliability of meeting the standard, the net benefits from agricultural production and the recovery time.

Two different policies were considered: spatially distributed fertilizer standards or quotas (obtained through multi-objective optimization) and fertilizer prices. The multi-objective analysis allows to compare the achievement of the different policies, Pareto fronts (or efficiency frontiers) and tradeoffs for the set of mutually conflicting objectives. The constraint method is applied to generate the set of non-dominated solutions. The multi-objective framework can be used to design groundwater management policies taking into consideration different stakeholders' interests (e.g., policy makers, agricultures or environmental groups).

The methodology was applied to the El Salobral-Los Llanos aquifer in Spain. Over the past 30 years the area has undertaken a significant socioeconomic development, mainly due to the intensive groundwater use for irrigated crops, which has provoked a steady decline of groundwater levels as well as high nitrate concentrations at certain locations (above 50 mg/l.). The results showed the usefulness of this multi-objective hydro-economic approach for designing sustainable nitrate pollution control policies (as fertilizer quotas or efficient fertilizer pricing policies) with insight into the economic cost of satisfying the environmental constraints and the tradeoffs with different time horizons.