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Managing conflicting objectives in hydro-economic models: A viability approach

jean christophe pereau
Bordeaux university, GREThA, Economics, France (jean-christophe.pereau@u-bordeaux.fr)

In aquifers managed with quotas, water agencies are facing conflicting objectives between ensuring minimum environmental flows for the preservation of groundwater-dependent ecosystems and satisfying the water claims of the farmers to irrigate their crops. Handling the potential conflict between economic and environmental objectives is a major concern to achieve sustainability. This paper analyses the existing trade-off between these objectives as a problem of constraints fulfillment and uses the viability method to adress this conflict.

Hydroeconomic models are generally developed as constraint optimization problems with environmental constraints represented by minimum flow requirements. At each period, the dynamics of an aquifer depend on the balance between the natural recharge, the natural discharge and the amount of extracted water. The natural discharge consists in water flows which sustain groundwater dependent-ecosystems. This natural discharge is assumed to be an affine function of the water table. It allows to defined a critical boundary value of the water table for which the natural discharge is nil. A first requirement of a sustainable management is then to keep the water table above this critical value.

The allocation of water quotas to farmers is also a problem of constraint. The use of market-based instruments such as tradable permits has been proposed as a promising way to replenish an aquifer or to efficiently manage groundwater aquifers for irrigated agriculture. Tradable permits ensure that water will be used by farmers with maximum efficiency. However like all "cap and trade" systems, the way the "cap" which consists in the available amount of water for users is set, remains a difficult issue. A second requirement of a sustainable management is then to implement relevant strategies in the allocation of water quotas for every farmer by a regulating agency.

To deal with these two requirements which take the form of constraints, the use of the viability approach has shown to be well-adapted. This paper developped a dynamic hydro-economic model in discrete-time using the viability approach. The viability kernel that defines the states of the resource yielding intertemporal feasible paths able to satisfy the set of constraints over time is analytically identified. The associated set of viable quota policies and the trade-off between food production and ecosystem conservation objectives are characterized.

The theoretical results of the paper are illustrated with numerical simulations based on the

Western La Mancha aquifer in Spain.