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Discussion of "Design and Evaluation of Irrigation Water Pricing Policies for Enhanced Water Use Efficiency" by Sayed Ali Ohab-Yazdi and Azadeh Ahmadi

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Today's agriculture in many parts of the developing world suffers from utter shortages in irrigated and rain-fed agriculture (Falkenmark and Rockström 2006). Such conditions call for a shift from current planning and management of water resources as exemplified in various studies that include reservoir operation (Ahmadi et al. 2014; Bolouri-Yazdeli et al. 2014), groundwater resources (Bozorg-Haddad et al. 2013; Fallah-Mehdipour et al. 2013b), conjunctive use operation (Fallah-Mehdipour et al. 2013a), water project management (Orouji et al. 2014), qualitative management of water resources systems (Orouji et al. 2013; Shokri et al. 2014), and water distribution systems (Seifollahi-Aghmiuni et al. 2013; Soltanjalili et al. 2013; Beygi et al. 2014). Applying economic measures such as marginal-cost water pricing and other water-management tools in water resources has shown promising results (Rogers et al. 2002; Ward and Pulido-Velazquez 2008). Yet, as the authors of the original paper wrote, most efforts aimed at water supply management have neglected the potential advantages of water demand management.

The original paper proposed water pricing policies along with incentive strategies through subsidies to farmers with the aim of improving water-use efficiency. A genetic algorithm–based optimization model was implemented to obtain the potential maximum net benefit by choosing the optimal crop pattern and water allocation scheme. The economic value of water was calculated using a combination of mathematical programming and residual methods within an optimization framework. The authors assumed in their model that water prices increase at the same time that subsidies are given to farmers to encourage them to use efficient irrigation technologies, causing an improvement in water-use efficiency. The results of their study illustrated a significant reduction in water consumption because of the enforced new water pricing policies.

Although the authors of the original paper succeeded in capturing the essence of water pricing policies and portrayed the benefits of such procedures, the discussers were compelled to highlight several pertinent issues and make suggestions to expand on the findings of the original paper. This discussion covers modeling and optimization topics of the original paper. The modeling topics pertain to the mathematical functions [objective function (OF) and constraints], economic issues, and general assumptions made in the original paper. The optimization topics are focused on the genetic algorithm (GA) optimization tool and its parameter selection.

Modeling Topics

1. Eq. (1) is used to express the *Benefit* in the original paper's model

$$Benefit = \sum_{t=1}^{y}\sum_{p=1}^{l}(py_{t,p} \times y_{t,p} \times a_p) \quad (1)$$

where l = number of agricultural crops; y = number of planning years; $py_{t,p}$ = price of crop p in year t (US\$/kg); $y_{t,p}$ = actual crop yield of crop p in year t (kg/ha); and a_p = cultivated area of crop p (ha).

The authors of the original paper assumed that the price of each crop is only influenced by time. However, the law of supply and demand states that all else being equal, the larger the production of an agricultural commodity, the lower its price. For this reason, as the area under cultivation for each crop expands, one can expect lower prices for the crop unless there is a concomitant rise in demand for the crops. This dynamic interaction of supply and demand partially explains the high price for crops with limited cultivation such as walnuts and low prices for major crops such as wheat in the original paper's study area.

2. Eq. (2) was used in the original paper to calculate the total crop production

$$y_{t,p} = Ym_{t,p} \times \prod_{k=1}^{m}\left[1 - ky_{t,p} \times \left(1 - \frac{ws_{t,k} + G_{t,k}}{Demand_{t,k}}\right)\right] \quad (2)$$

where $ws_{t,k}$ = surface water allocation in month k of year t (m^3); $G_{t,k}$ = groundwater withdrawal in month k of year t (m^3); $Demand_{t,k}$ = water demand in month k of year t; $ky_{p,k}$ = sensitivity coefficient for crop p in month k; $Ym_{t,p}$ = maximum crop yield of crop p in year t (kg/ha); and m = number of months. Some of the crops (if not all) mentioned in the original paper's case study have limited life spans, during which the crops require watering for nourishment ($Demand_{t,k}$). However, the value of $Demand_{t,k}$ is equal to zero for the remaining months of the year. When $Demand_{t,k}$ equals zero, the division on the right-hand side of Eq. (2) becomes undefined (division by zero). Logic dictates that in such cases, the value for $ws_{t,k} + G_{t,k}/Demand_{t,k}$ must equal 1.

3. The value of the pumping efficiency (η) was assumed as a constant through the entire operation horizon in the original paper. Yet, the efficiency value for each pump will decline through time.

4. Eq. (3), which was used in the original paper as a constraint, prescribes that the total water allocation must be less than the available water (aw)

$$\sum_{t=1}^{y}\sum_{k=1}^{m}(ws_{t,k} + G_{t,k}) \le aw \quad (3)$$

However, using such a constraint could lead to infeasible results. To understand this point, consider the values shown in Table 1, in which R_{i-1} = recharge value of the previous period (m^3). For simplicity only 1 year was considered in composing Table 1, where it is seen that the values considered for surface and groundwater withdrawals satisfy Eq. (3). Yet, they are infeasible, because if no water is available, no withdrawal can be made. Using Eq. (3) can cause

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Table 1. Sample of Possible Outcomes of Surface and Groundwater Withdrawal for 1 Year of Optimization

Variables (m^3)	January	February	March	April	May	June	July	August	September	October	November	December	Summation
	Months												
aw	20	12	4	0	0	0	0	0	0	0	0	40	76
R_{i-1}	20	0	0	0	0	0	0	0	0	0	0	40	60
$ws_{t,k}$	2	3	4	3	2	2	2	1	1	1	1	1	23
$G_{t,k}$	6	5	1	1	1	1	1	1	1	1	1	1	21

infeasible withdrawal values when the amount of required water exceeds aw. To avoid such errors, Eq. (4) should replace Eq. (3) of the discussion paper [Eq. (10) of the original paper]

$$ws_{t,k} + G_{t,k} \leq aw_{t,k} \quad \forall \ t, k \tag{4}$$

where $aw_{t,k}$ = available water in month k of year t (m^3).

Optimization Topics

Many engineering optimization problems contain coupled simulation-optimization models. The optimization model searches for a set of decision variables within the decision space, which are input into the simulation model. The GA has proven to be an acceptable algorithm owing to its effectiveness in solving various complex water resources problems (Nicklow et al. 2010).

The authors of the original paper utilized a GA optimization model to search the decision space for the optimal values of decision variables. Basically, the GA generates random sets (called generations or populations) of decision variables (called chromosomes), some of which might be infeasible. Through a set of iterations, the GA transforms the initial generation into a new one. These iterations continue until they reach a stopping criterion, when, hopefully, the surviving decision variables are either optimal or near optimal.

Usually, there are four criteria to establish the convergence of the GA: (1) differences between the best chromosomes of the new and the previous generations, (2) time, (3) the number of generations, and (4) functional evaluations. Using functional evaluations, which are equal to the population size × number of iterations, as the convergence criterion has several merits (Fallah-Mehdipour et al. 2014). The authors of the original paper were mute on their choice of stopping criteria. Yet, as this discussion has implied, the stopping criteria could affect the optimization results.

References

Ahmadi, M., Bozorg-Haddad, O., and Mariño, M. A. (2014). "Extraction of flexible multi-objective real-time reservoir operation rules." *Water Resour. Manage.*, 28(1), 131–147.

Beygi, S., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2014). "Bargaining models for optimal design of water distribution networks." *J. Water Resour. Plann. Manage.*, 10.1061/(ASCE)WR.1943-5452.0000324, 92–99.

Bolouri-Yazdeli, Y., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2014). "Evaluation of real-time operation rules in reservoir systems operation." *Water Resour. Manage.*, 28(3), 715–729.

Bozorg-Haddad, O., Rezapour Tabari, M. M., Fallah-Mehdipour, E., and Mariño, M. A. (2013). "Groundwater model calibration by meta-heuristic algorithms." *Water Resour. Manage.*, 27(7), 2515–2529.

Falkenmark, M., and Rockström, J. (2006). "The new blue and green water paradigm: Breaking new ground for water resources planning and management." *J. Water Resour. Plann. Manage.*, 10.1061/(ASCE)0733-9496(2006)132:3(129), 129–132.

Fallah-Mehdipour, E., Bozorg-Haddad, O., and Mariño, M. A. (2013a). "Extraction of optimal operation rules in aquifer-dam system: A genetic programming approach." *J. Irrig. Drain. Eng.*, 10.1061/(ASCE)IR.1943-4774.0000628, 872–879.

Fallah-Mehdipour, E., Bozorg-Haddad, O., and Mariño, M. A. (2013b). "Prediction and simulation of monthly groundwater levels by genetic programming." *J. Hydro-environ. Res.*, 7(4), 253–260.

Fallah-Mehdipour, E., Bozorg-Haddad, O., and Mariño, M. A. (2014). "Discussion of 'Performance of shuffled frog-leaping algorithm in finance-based scheduling' by Anas Alghazi, Shokri Z. Selim, and Ashraf Elazouni." *J. Comput. Civ. Eng.*, 10.1061/(ASCE)CP.1943-5487.0000265, 327–328.

Nicklow, J., et al. (2010). "State of the art for genetic algorithms and beyond in water resources planning and management." *J. Water Resour. Plann. Manage.*, 10.1061/(ASCE)WR.1943-5452.0000053, 412–432.

Orouji, H., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2013). "Modeling of water quality parameters using data-driven models." *J. Environ. Eng.*, 10.1061/(ASCE)EE.1943-7870.0000706, 947–957.

Orouji, H., Bozorg-Haddad, O., Fallah-Mehdipour, E., and Mariño, M. A. (2014). "Extraction of decision alternatives in project management: Application of hybrid PSO-SFLA." *J. Manage. Eng.*, 10.1061/(ASCE)ME.1943-5479.0000186, 50–59.

Rogers, P., De Silva, R., and Bhatia, R. (2002). "Water is an economic good: How to use prices to promote equity, efficiency, and sustainability." *Water Policy*, 4(1), 1–17.

Seifollahi-Aghmiuni, S., Bozorg-Haddad, O., and Mariño, M. A. (2013). "Water distribution network risk analysis under simultaneous consumption and roughness uncertainties." *Water Resour. Manage.*, 27(7), 2595–2610.

Shokri, A., Bozorg-Haddad, O., and Mariño, M. A. (2014). "Multi-objective quantity-quality reservoir operation in sudden pollution." *Water Resour. Manage.*, 28(2), 567–586.

Soltanjalili, M., Bozorg-Haddad, O., and Mariño, M. A. (2013). "Operating water distribution networks during water shortage conditions using hedging and intermittent water supply concepts." *J. Water Resour. Plann. Manage.*, 10.1061/(ASCE)WR.1943-5452.0000315, 644–659.

Ward, F. A., and Pulido-Velazquez, M. (2008). "Water conservation in irrigation can increase water use." *PNAS*, 105(47), 18215–18220.

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