Meeting challenges of the *Blue Revolution*: increasing irrigation efficiency with soft-computing optimisation methods

Niels Schütze*, Thomas Wöhling, Michael de Paly, Gerd H. Schmitz
Institute of Hydrology and Meteorology, Dresden University of Technology, Germany

*Email: ns1@rcs.urz.tu-dresden.de

1 The backround of the "Blue Revolution"

Water is a limited resource and the dramatically increasing world population requires a significant increase in food production. The enormous challenge to feed additional 2 billion people in 2030 can only be met by an expanding the irrigated agriculture in developing countries. Water consumption will increase by 14 percent in the next thirty years although some developing countries are already using 40% of their renewable freshwater for irrigation. Thus, the FAO calls for a "Blue Revolution" in water management in order to improve the generally low water use efficiency in irrigation (about 38%).

2 The nested optimisation problem

For improving both, crop yield and water use efficiency, the usual optimisation strategy in furrow irrigation at the field level considers scheduling parameters, i.e. **when and how much** to irrigate, as well as control parameters, i.e. the **inflow and the cutoff time**, for each water application. Due to the fact, that these parameters are interconnected, they have to be evaluated simultaneously for attaining an optimal water application efficiency. Unsolved problems exists due to the complexity of the optimisation problem and/or rough empirical descriptions of the relevant processes in furrow irrigation.

3 Why using genetic algorithms when dealing with the outer optimisation problem?

The considered optimisation problem in furrow irrigation is **hard** in the sense that the target function has many locally optimal solutions and the number of optimization variables ,i.e. the number of irrigations is unknown apriori. Thus, finding the global solution is **neither not possible with classical deterministic optimisation techniques nor with common modern approaches** like simulated annealing (SA) or shuffled complex evolution (SCE-UA). For this reason, a tailored genetic optimisation technique (GA) is employed to find a near-optimal solution of the outer optimisation problem **(when and how much to irrigate)** within acceptable computation time. The GA combines the flexibility to confine the parameter space to valid solutions with the possibility of an extensive parallel processing.

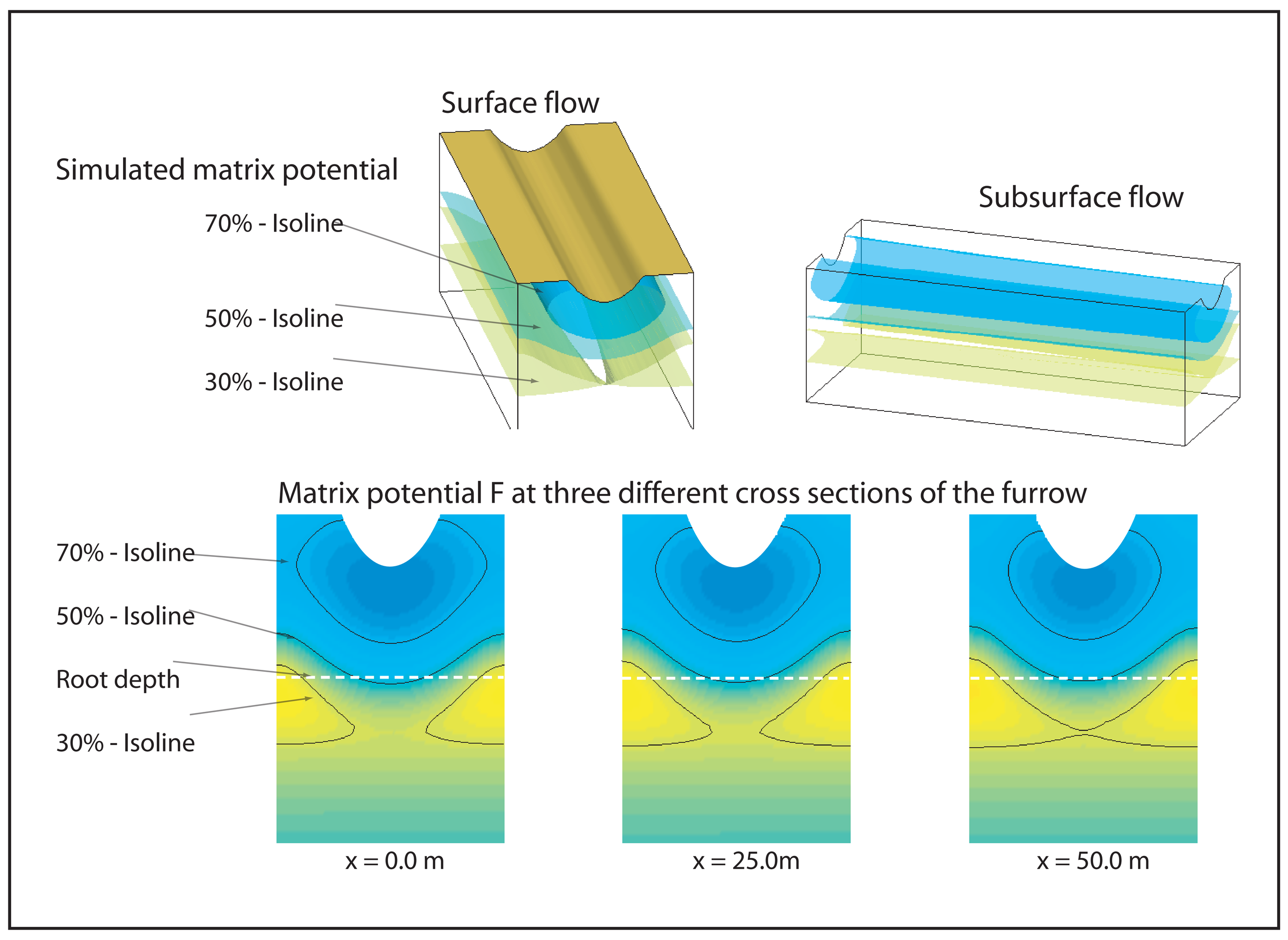


Fig.1: Furrow Irrigation Model for a whole cropping cycle (FIM) - Redistribution

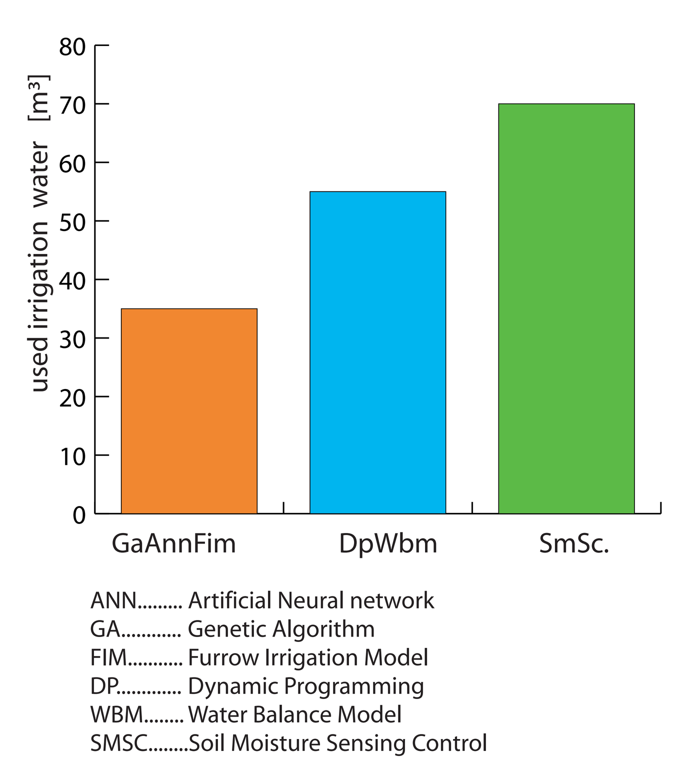
Why using artificial neural networks for solving the inner optimisation problem?

The control parameters for each water application on the field **(inflow and the cutoff time)** are calculated by an artificial neural network (ANN) based on self-organized maps (SOM). The new SOM-MIO architecture was developed, which allows performing simulation tasks as well as solving inverse problems after a single training: - the Self-Organizing Map with Multiple Input/Output option- . **The SOM-MIO approximates the inverse solution of the coupled numerical surface/subsurface flow model and thus, enormously speeds up the overall performance of the complete optimisation tool.** Furthermore, the robustness and stability of ANN-based applications could prove to be useful in numerical schemes, such as nonlinear optimisation or Monte Carlo methods.

4 Results

We compared different optimization strategies on a real-case irrigation field. A limited amount of water had to be distributed with an optimal irrigation schedule by (i) classical optimisation techniques, i.e. dynamic programming plus a water balance model (DpWbm), and (ii) the new strategy consisting of the dynamic furrow iriigation model, genetic algorithm and a neural network (GaAnnFim). To meet a specific yield after a 130 days growing period the required water volume was calculated with the above optimisation strategies. Fig. 2 shows their results together with those of a sensor based real-time control system (SMSC). It illustrates the drastic decrease of required by the new strategy while achiving the same yield like the other methods.

Fig.2: water requirement of different scheduling algorithms achieving the same yield on a virtuell test field with maize



5 Conclusions and further developments

There is a high potential to increase irrigation efficiency when rigorous physically based modeling and soft-computing optimisation methods are combined for controlling onfield water supply in furrow irrigation. This requires both, improvements in realistic modelling of the subsurface flow and predictive crop growth models including the stochastic nature of climate factors. In addition, the optimisation tool needs further development under economic and social aspects of rural systems towards a sustainable agricultural water management.

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