Proceeding Series of the Brazilian Society of Computational and Applied Mathematics, v. 9, n. 1, 2022.

Trabalho apresentado no XLI CNMAC, Unicamp - Campinas - SP, 2022.

Proceeding Series of the Brazilian Society of Computational and Applied Mathematics
Preprint

Automated optimized irrigation systems for small farmers in a subtropical region

Iris Marcela Jara [1]
Blanca Del Puerto [2]
Margarita Ruiz Olazar [3]
Comunera University, Asunción, Paraguay
Christian E. Schaerer [4]
CIMA Centro de Investigación en Matemática, San Lorenzo, Paraguay

Several Latin American countries have an economy strongly based on agricultural/livestock sector, where dependence on water plays a predominant role. This dependency is being observed in a cyclical way due to el *Niño*, la *Niña*, and climatic changes. Among the producers, those of small and medium-size, based mainly on family farming, are the ones that suffer the most from the consequences of water scarcity. Paraguay is a specific case since the drought, which has been going on for two years, is causing significant damage. This situation puts the food and economic security of small and medium-sized producers at risk. The need then arises to promote sustainable, optimized management and conservation of water in Paraguayan agriculture.

To optimize water resources, several work have been encountered in the literature. In [4] an artificial neural network is used to predict the hydrological and meteorological data (such as rainfall, temperature, humidity, and wind velocity) based on data from previous years. Other works also obtain a planting schedule based on the needs of the plants from the prediction data. In [3] was developed a mathematical modeling tool that helps in the decision-making process for the problem of planning agricultural production and efficient water management.

Among the works that have implemented operations research techniques to efficiently optimize water resources, we can mention [5] present in their study a simulation-optimization model for crop optimal irrigation scheduling under uncertainty developed to maximize the net benefit, and finally [2], that develop an optimization algorithm for an intelligent irrigation system, in order to create a substantial opportunity for water savings in the Panamanian agricultural sector.

In this work, we seek for an optimized irrigation system that allows minimizing water consumption in a multi-plantation of a (small and medium) land farmer in Paraguay, avoiding waste and satisfying the consumption needs of each plantation. We start from the basis that small and medium producers have a certain diversity of plantations that must be satisfied daily. Let x_{nt} optimal flux of water per hour per irrigation line, x_{safe} maximum secure flux of water per hour per irrigation line, x_{max} maximum system flux per period of irrigation, T period of irrigation, r_n initial time of irrigation, d_n final time of irrigation, n each irrigation lines, N total number of irrigation lines, w_n water necessity per day. Hence, the following constraints are imposed to all irrigation

[1] irisjar@gmail.com
[2] blank.dp@gmail.com
[3] margarita.ruiz@ucom.edu.py
[4] chris.schaerer@cima.org.py

lines:

$$\sum_{n=1}^{N} x_{nt} \leq x_{max}, \forall t \in [r_n, d_n], \tag{1}$$

$$\sum_{t=r_n}^{d_n} x_{nt} = w_n \forall n, \tag{2}$$

$$0 \leq x_{nt} \leq x_{safe}, \forall n \; \forall t \in [r_n, d_n]. \tag{3}$$

To satisfy to each irrigation line necessity of water, the following optimization functional is considered [2]:

$$J = \left(\sum_{n=1}^{N} \sum_{t=r_n}^{d_n} (x_{nt} - w_n)^2 \right), \tag{4}$$

which represents the quadratic deviation between the administrated flux of water and the necessity for each irrigation line.

Expression (4) is minimized subject to the constraints (1) using the GEKKO library for Python [1], as a machine learning and optimization toolbox [1]. For the test, we consider 10 plantation lines. Each of them with specific water necessities. The mean of the complete necessity of water is 4.7 liters per day per plant, a secure of 3 liters per day per plant, and a maximum flux of 30 liters for the complete plantation. For all cases, we consider that the water is distributed uniformly during the period of irrigation. Two scenarios are explored: (a) maximum secure flux of water per hour per irrigation line, and (b) half of the maximum secure flux of water per hour per irrigation line uniformly distributed at each irrigation line. In the first scenario, the average water-saving is 60%, while in the second scenario, the water-saving is 20%. These results show a reduction in water waste, even satisfying the water necessities of each irrigation line. The average running time of the GEKKO algorithm is 0.13 seg. The results motivate the implementation of a web-responsive application codified in Python which allows producers to access the application through their cellphones for obtaining optimized personalized information about the plan of distribution of irrigation for the complete plantation.

References

[1] L. Beal et al. “GEKKO Optimization Suite”. In: **Processes** 6.8 (2018), p. 106. DOI: `10.3390/pr6080106`.

[2] E. Collado and Y. Saez. “Sistema de Riego Inteligente para optimizar el consumo de agua en cultivos en Panamá”. In: **Proceedings of the 15th LACCEI International Multi-Conference for Engineering, Education and Technology**. 2017.

[3] N. M. Cid Garcıa. “Planificación de la producción agrıcola y manejo eficiente del agua en un sistema de irrigación”. PhD thesis. Universidad Autónoma de Nuevo León, 2012.

[4] M. I. Irawan et al. “Intelligent Irrigation Water Requirement System Based on Artificial Neural Networks and Profit Optimization for Planning Time Decision Making of Crops in Lombok Island”. In: **Journal of Theoretical and Applied Information Technology** 58.3 (2013), pp. 657–671.

[5] J. Li et al. “Optimization of irrigation scheduling for spring wheat based on simulation-optimization model under uncertainty”. In: **Agricultural Water Management** 208 (2018), pp. 245–260. ISSN: 0378-3774. DOI: `https://doi.org/10.1016/j.agwat.2018.06.029`. URL: `https://www.sciencedirect.com/science/article/pii/S0378377418308849`.