COLLECTIVE IRRIGATION NETWORK DESIGN AND MANAGEMENT FOR ENERGY OPTIMIZATION: THE "CINTEGRAL" TOOL

LA GESTION ET LA CONCEPTION D'UN RESEAU D'IRRIGATION COLLECTIF POUR LA OPTIMIZATION DE L'ENERGIE : L'OUTIL « CINTEGRAL »

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ABSTRACT

Traditional solid-set irrigation designs were performed to ensure 300 kPa at the nozzle of the impact sprinkler. Encouraging results were provided by different studies when reducing to 200 kPa at the nozzle.A collective sprinkler irrigated area, La Violada, was originally designed to operate at 300 kPa at the sprinkler nozzle (Violada300), in this research the collective network has been redesigned to operate at 200 kPa (Violada200). CINTEGRAL tool was used to simulate crop yield, irrigation performance and economic productivity for Violada300 and Violada200. The same crop pattern was simulated for both cases. Differences on crop yield between both cases were not relevant when yields are high (> 95%), for low yields (< 95%) Violada300 presentedthe highest yields, especially for corn. Seasonal irrigation performance resulted larger for corn and barley for Violada200 case since for alfalfa and peasViolada300 case performs better.When considering exploitation cost (water and electricity cost) and investment cost (pumping station, collective and on-farm networks),Violada200 obtains the largest economic productivity.

RÉSUMÉ

Les conceptions traditionnelles d'irrigation par arrosage ont été effectuées pour assurer 300 kPa à la buse de l'arroseur. Des résultats encourageants ont été fournis par différentes études lorsque réduisant à 200 kPa à la buse. Un périmètre collectif d'arrosage irrigué, La Violada, a été conçu pour fonctionner à 300 kPa à la buse d'arrosage (Violada300), dans cette recherche, le réseau collectif a été repensé afin d'exploiter à 200 kPa (Violada200). CINTEGRAL outil a été utilisé pour simuler le rendement des cultures, performance de l'irrigation et la productivité pour Violada300 et Violada200. Le même modèle de récolte a été simulé dans les deux cas. Différences sur la production agricole entre les deux cas n'étaient pas pertinente quand les rendements sont élevés (> 95 %), de faibles rendements (< 95 %) Violada300 a présenté les rendements les plus élevés, surtout pour le maïs. Performance de la saison d'irrigation a entraîné plus grande pour le maïs et l'orge pour Violada200 cas mais pour la luzerne et le pois Violada300 cas est maïeur. Si l'on considère le coût d'exploitation et le coût de l'investissement (station de pompage, des réseaux collectifs et à la ferme), Violada200 obtient la plus grande productivité économique.

Keywords:network irrigation design, low pressure sprinkler irrigation …

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1. Introduction

Be efficient with the use of water (apply irrigation when and in the amount that the crop needs) is not enough if water is applied by pressurized irrigation systems. In addition, it is necessary to be efficient with the use of energy (reducing the energy per unit volume of water) and schedule the irrigation at low energy cost periods. Aware of these challenges, many research works have been focused on improvement of the energy efficiency of irrigation facilities, optimizing pumping stations and irrigation network designs (Carrillo-Cobo et al, 2010; Lamaddalena and Khila, 2012). However, it is necessary to move forward in the energy optimization, paying attention also to irrigation in the plot.

Traditional solid-set irrigation designs were performed to ensure 300 kPa at the nozzle of the impact sprinkler. Encouraging results were provided by Playán et al. (2006) for the same impact sprinkler when reducing the pressure from 300 kPa to 200 kPa at the nozzle. Recently the development of new impact sprinkler specially designed to operate at reduced pressures, 200 kPa, that were based on the developments of Kincaid (1991), provides another research line to explore.

2. Material and Methods

The Violada irrigated area is one of the five pumped areas of the Almudevar irrigation district. The study area irrigates 1458 hectares divided in 107 hydrants. The pumping station is controlled by an automaton that ensures a pressure of 300 kPa at the sprinkler nozzle. The irrigation network design was performed accounting with this pressure requirement that results in a total pumping power installed of 1400 kW. The head at the pumping station resulted of 79 m.w.p. The current design was obtained from the District office and will be called in this paper Violada300. The farmer organized to perform the on-farm irrigation networks cooperatively, resulting in a very homogeneous solid-set designs arranged on 18 m by 18 m with sprinklers equipped with double nozzle of 4,4 mm and 2,4 mm. The irrigation depth of the plots was 5.3 mm h^{-1}.

The Violada collective network was redesigned to reduce the required pressure at the sprinkler nozzle to 200 kPa (Violada200), but maintaining the hydrant discharge. The new design requires a head at the pumping station of 69 m.w.p. The new design affects also the on-farm network designs since the discharge at the hydrant point was the same but the sprinkler discharge was reduced with the pressure, reducing the number of sector per plot. Also the power requirement at the pumping station was reduced to 1200 kW. The irrigation depth for this case was 4.25 mm h^{-1}.

The CINTEGRAL tool was developed by the RAMA group in collaboration with the company CINGRAL S.L. CINTEGRAL was a collective network design evaluation tool composed by five modules that interchange input and output data to evaluate the effects of irrigation network design, on-farm irrigation design, meteorology and crop pattern on economical productivity. The modules are the following:

1. Collective irrigation simulation module, EPANET (Rossman,2000).
2. On-farm sprinkler irrigation simulation module, AdorSprinkler (Playán et al., 2006)
3. Crop simulation module, AdorCrop (Dechmi et al., 2004).
4. Irrigation decision module, AdorDecision (Zapata et al., 2009).
5. Optimization module to adjust the electric contract to the current network design.

The input data required to simulate the crop yield of the irrigated area were intensive and are:

1. Violada irrigation network design with EPANET. File names: Violada300.inp and Violada200.inp.
2. On-farm data: hydrant number, number of plots, number of sectors per plot, soil characteristics and crop data. File names: Violada300.ado and Violada200.ado
3. Irrigation management data: solid-set arrangement, sprinkler type and nozzle sizes, electricity supply contract (arranged in six tariff levels of different cost), irrigation control variables. Violada300.rie and Violada200.rie.
4. Meteorological data: two sources of data, average daily data for crop modeling, and semihourly data for irrigation modeling and decision making. The irrigation season selected was 2014.
5. Economic data: income by harvesting per crop, crop production cost not including water and energy (computed by the simulation model), collective network and on-farm network investment cost and their financial conditions.

A comparison betweencrop yield, seasonal irrigation performance and economical productivity of LaViolada irrigated area was performed for both collective irrigation networks (Violada300 and Violada200). The principal differences between the cases are the irrigation performance (simulated), the collective network design and its cost, the on-farm irrigation design and its cost (input data) and the power contract and its cost (simulated).

The 2014 irrigation season was simulated, ensuring the same crop at each plot and the same soil conditions for both cases. The crop distribution pattern was obtained from previous works in the area (Stambouli et al., 2014), with 40% of the total area cropped with corn, 35% with alfalfa, 10% with barley and 15% with peas. The electric contract in each case was adjusted by the optimization module ensuring in both cases the large net income

3. Results and Discussion

Figure 1 presents the comparison of theplot relative yield (%) for the two analysed cases. The comparison has been performed per crop. In general, there is a good correlation between yields for both cases, especially for alfalfa and peas crops. Largest yields were obtained for corn for the 300 kPa irrigation case when corn production is lower than 90%. The conclusion is that reducing the pressure at the sprinkler nozzle from 300 to 200 kPa has not a relevant effect on crop yields, except for some cases of corn.

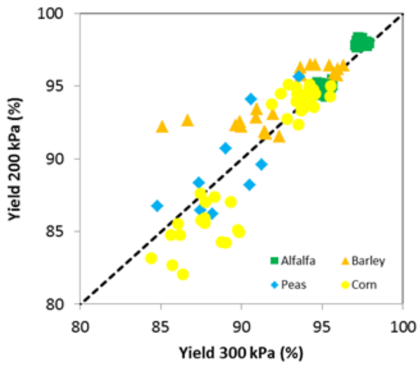

Figure 1*. Comparison between relative yield for both analysed cases 300kPa and 200kPa at the sprinkler nozzle. The comparison has been performed per crop.*

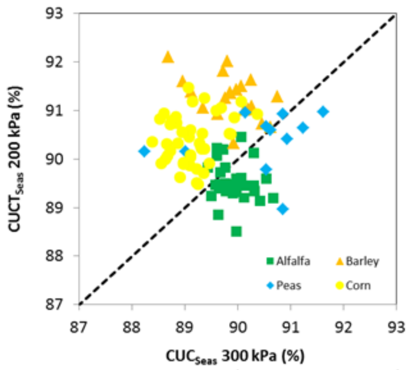

Figure 2*. Comparison between seasonal Uniformity Coefficient for both analysed cases 300 kPa and 200 kPa at the sprinkler nozzle. The comparison has been performed per crop.*

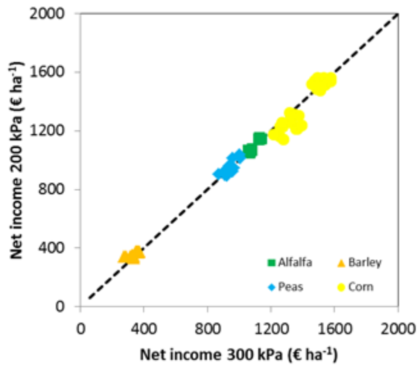

Figure 3*. Comparison between plot Net Income without considering water and energy cost for both analysed cases, 300 kPa and 200 kPa at the sprinkler nozzle. The comparison has been performed per crop.*

Figure 2 presents the comparison of the plot seasonal Christiansen Uniformity Coefficient for both cases. Since irrigation depth was different the irrigation dates were not coincident and the seasonal irrigation performance (CUC) showed clear differences between cases. The seasonal Uniformity resulted larger for corn and barley for the 200 kPa than for the 300 kPa case and the inverse happens for alfalfa and peas.

Figure 3 presents the comparison of the plot Net Income without considering water and energy cost (€ ha^{-1}) per crop and for the two analysed cases. Net income was computed considering theincorme per crop harvest and the production cost of the crop (without water and energy). With the input economic data and the simulated yield, the net income were similar for all the crops except for corn, that presents a larger income for the 300 kPa case than for the 200 kPa case. Corn has the larger net income but also has the largest risk since the production cost is the largest and the effect of water stress in corn yield was also the most important between the analysed crops.

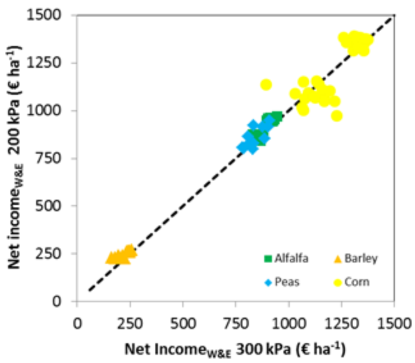

Figure 4*. Comparison between plot Net Income considering water ana energy cost for both analysed cases, 300 kPa and 200 kPa at the sprinkler nozzle. The comparison has been performed per crop.*

Figure 4 present the Net Income incorporating the water and energy cost(€ ha^{-1}). The water and overall the energy cost has an important impact on the production cost, reducing the net income in around 200 € ha^{-1} for corn and alfalfa, around 120 € ha^{-1} for peas and around 100€ ha^{-1} for barley. The largest energy cost for the 300 kPa case equilibrates the differences between the corn yields, resulting in very similar results.

The consideration of the networks and pumping stations investment cost will provide a larger difference to the 200 kPa case compared with the 300 kPa. For the particular case analysed, LaViolada, the reduction of the pressure requirements at the sprinkler nozzle resulted clearly an advantage, since the reduction on energy and investment cost is clear and compensate the small yield loss of corn. The CINTEGRAL software is a valuable tool to analysedifferences of network designs on crop production and energy and water consumption.

4 CONCLUSIONS.

1. The CINTEGRAL software results a valuable tool to analyse the agronomical and economical productivity of alternative network designs of a collective irrigation district.

2. For La Violada irrigated area, the new design and operational changes to irrigate at 200 kPa at the sprinkler nozzle resulted economically profitable because the reduction on the networks investment cost and the exploitation cost related with energy and water greatly compensate the slight reduction in corn yield.

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