IRRIGATION PUMPING EFFICIENCY AT SMALLHOLDINGS IN NORTH EAST BRAZIL

EFFICACITE DE POMPAGE DANS L'IRRIGATION A PETITE ECHELLE DE NORD-EST DU BRESIL

Luciano Mateos [1] Alexsandro Claudio dos Santos Almeida [2] José Antônio Frizzone [3]
Sílvio Carlos Ribeiro Vieira Lima [4]

ABSTRACT

Irrigation performance assessment has been conducted at the Baixo Acarau Irrigation District, Ceará, Brazil. The water source is the Acaraú River. Water is delivered through open channels and pumped on-farm to be applied with drip/trickle and micro-sprinkler systems. The district covers 8,335 hectares, divided into lots of large, medium and small sizes. The main crops are coconut and banana. In 2014, a comprehensive evaluation of the entire farm irrigation systems was conducted in a sample of 40 8-ha family lots. The evaluations included determinations of motor-pump efficiency based on flow rate measurements with portable ultrasonic flow meter, pressure measurements at the pump outlet, estimation of local head losses, and determinations of power consumption based on voltage and current intensity measurements. Pumping efficiency was overall poor. The consequences in terms of electricity cost and irrigation system performance should be examined. The existence of good-performing motor pumps gives hope for using benchmarking as technique for participatory learning and improvement.

RÉSUMÉ

L'évaluation de la performance d'irrigation a été réalisée dans le périmètre irrigué Baixo Acarau, Ceará, Brésil. La source d'eau est le fleuve Acaraú. L'eau est distribuée à travers de canaux à ciel ouvert et pompé à la ferme pour irrigué avec systèmes d'irrigation localisé. Le district couvre 8335 hectares, répartis en fermes de grande, moyenne et petite tailles. Les principales cultures sont coco et banane. En 2014, une évaluation complète des systèmes d'irrigation a été menée sur un échantillon de 40 fermes familiales de 8 ha. Les évaluations comportaient la détermination du rendement moteur-pompe, basée sur des mesures de débit avec débitmètre à ultrasons portable, des mesures de pression à la sortie de la pompe, l'estimation de pertes localisés d'énergie, et des estimations de consommation d'énergie basées sur mesures de la tension et l'intensité du courant. L'efficacité de pompage a été globalement mauvaise. Les conséquences en termes de coût de l'électricité et de la performance du système d'irrigation doivent être examinés. L'existence de motopompes avec bon performance donne de l'espoir pour l'utilisation de l'analyse comparative et d'apprentissage participatif pour l'amélioration.

Keywords: flow rate, pressure head, head loss, pump characteristic curve

[1] Research Sicentist, Instituto de Agricultura Sostenible (CSIC), Alameda del Obispo 14004, Córdoba, Spain, E-mail ag1mainl@uco.es
[2] Research Fellow, Universidade Federal da Grande Dourados, Rodovia Dourados à Itahum Km 12, 79804-970 Dourados, MS, Brazil, E-mail: alexsandroalmeida@ufgd.edu.br
[3] Professor, Escola Superior de Agricultura Luiz de Queiroz, Departamento de Engenharia de Biossistemas, Avenida Pádua Dias 11, 13418900 Piracicaba, SP, Brazil, E-mail: frizzone@usp.br
[4] Director, Instituto de Pesquisa e Inovação na Agricultura Irrigada - INOVAGRI, Rua João Carvalho 800, SALA 1102, Aldeota, 60140-140 Fortaleza, CE, Brazil, E-mail: silviocarlos@yahoo.com.br

1. Introduction

Smallholder irrigation has been suggested as means to get out of the poverty trap (Burney et al., 2013). Large scale development of smallholder irrigated agriculture can be realized by constructing collective irrigation schemes that become settlement for small farmers. Overall, smallholder large- and small-scale irrigation schemes have performed below expectations, although good-performing schemes and farmers are also found (Borgia et al., 2013). In Brazil, substantial investments have been made by the government and international funding agencies to construct public irrigation schemes. They performance is highly variable (Gonçalves et al., 2015), although they are viewed as important assets for rural development in the semiarid Brazilian North-East. By testing a number of different technologies and arrangements at the farm level, Burney et al (2014) have shown that interventions in the Sertão focused on efficient irrigation systems can help reduce the dependence of production systems from climate.

This paper is part of a larger study aiming to diagnose and improve on-farm irrigation performance in the Baixo Acaraú Irrigation District, Ceará, Brazil. Apparently, the opportunities for improving crop production and marketing are large. Reducing irrigation costs (due mainly to energy use for pumping) will also contribute to increase farm net revenue. The specific objective of this study is to evaluate pumping efficiency at smallholder farm lots in the Baixo Acaraú Irrigation District.

2. The irrigation district

The Baixo Acaraú Irrigation District (acronym in Portuguese, DIBAU) is located in the semiarid Brazilian North-East, in the state of Ceará, at latitude 3° 7' S and longitude 40° 5' W. Baixo Acaraú has tropical climate with dry summer. Rainfall concentrates between January and May (mean annual rainfall 1300 mm). Soils are sandy or sandy loam. The district was constructed in 2002 by the National Integration Ministry and later handed over to settlers who nowadays are associated under a Water Users Association that manages DIBAU. The district covers 8,335 ha divided into 501 farm lots of varying sizes: small (4-8 ha), medium (16-18 ha) and large (80-200 ha). The majority of the farm lots are family lots of 8 ha. The main crops are coconut (48%), banana (18%), guava (6%), orange trees (5%), and papaya (4%). Water is supplied to the district by a pumping station at the Acaraú River; then it is distributed to the farmers through an open channel distribution network. At the entrance of the farm lots, water is pressurized by pumping from a head tank and filtered to be applied with drip/trickle and micro-sprinkler systems. Typically, the 8-ha family lots are divided into 8 irrigation subunits (Fig. 1).

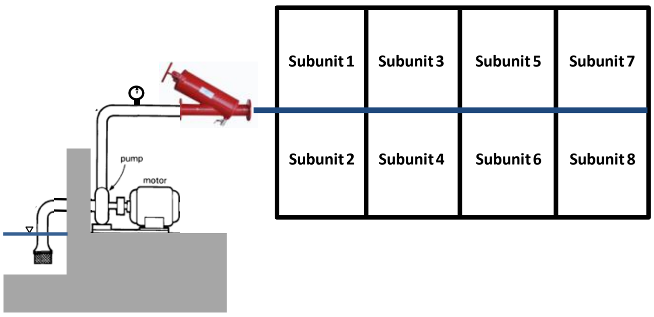

Figure 1. Sketch of the irrigation system head and irrigation units layout in a typical 8-ha family lot in the Baixo Acaraú Irrigation District

3. Material and methods

In 2014, a comprehensive evaluation of the entire farm irrigation systems was conducted in a sample of 40 8-ha household lots. The evaluations included noting motor and pump characteristics as displayed in the respective plates, visual inspection of the motor-pump state, sketching the motor pump configuration, inquiring about age and maintenance, and determination of the motor-pump efficiency (E_p), defined as the ratio between the pump power (P_p) and the power supplied by the motor (P_m):

$$E_p = 100\ P_p / P_m \quad (1)$$

All pumps in DIBAU are powered by three-phase electric motor, thus P_m was calculated as:

$$P_m = \eta\ \sqrt{3}\ V\ I\ \cos\varphi \quad (2)$$

where V is voltage, I current intensity, η motor efficiency and cosφ the power factor. V and I were measured using a digital clamp multimeter (Minipa, ET-3200, Brazil), while η and cosφ were taken from the motor plate.

Pump power was calculated as:

$P_p = \rho\ g\ Q\ H$ (3)

where ρ is water density, g the acceleration due to gravity, Q the pump discharge, and H the dynamic head at the pump outlet with respect to the water level at the entrance tank. Q was measured with a portable ultrasonic flow meter (PCE Instruments PCE 100-H, UK). H was determined from pressure measurements at the pump outlet using a manometer (Bratal, work ranges from 0 to 4 and 6 bar, Brazil) and considering local head losses along the suction and discharge pipes as well as the velocity head at the point of pressure measurement. Pump characteristic curves were taken from the manufacturers catalogues.

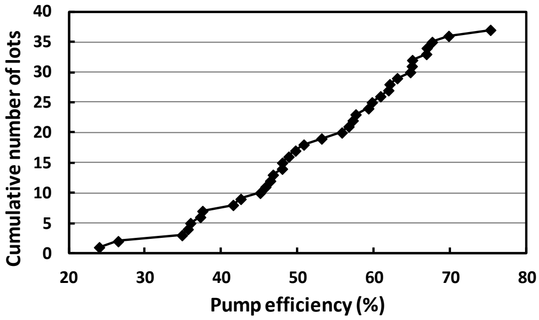

Figure 2. Cumulative distribution of pump efficiency in the evaluated farm lots of the Baixo Acaraú Irrigation District.

4. Results and discussion

All motors have rated power of 10 kw except two who have 12.2 kw. All pumps are centrifugal. The most common pump brands are INAPI (model 12DLC, 3500 rpm, impeller of 168 mm), KSB (model Megabloc 40160R with impellers of 151, 160 or 174 mm), KING (model C10R, 3500 rpm, impeller of 179 mm) and IMBIL (model 40125, 3500 rpm, impeller of 133mm), although other pump models are found. The year of acquisition of the pumps varied from 2003 to 2012.

Pump efficiency varied from farm lot to farm lot greatly (Fig. 2). It was less than 50% in 17 of the 37 farm lots where it could be determined (Fig. 2). When compared to the efficiency provided by the pump manufacturer, only two pumps showed the efficiency in the catalogue (pump catalogues were available for the models of 26 of the 40 evaluated pumps). Fig. 3 shows the operation point in the H-Q (Fig. 3a) and E_p-Q (Fig. 3b) plane for the 10 evaluated INAPI pumps. The operation data points were at varying distance from the catalogue curves, that enveloped the points cloud. The lowest E_p in the INAPI data set was 35%, while according to the catalogue curve it should be 70%. For the same lot, H was 27.2 m, while it should be 49.5 m for the measured discharge.

In order to benchmark efficiency, all pump models were pooled using the ratio between the actual efficiency and the catalogue pump efficiency for the actual discharge. The resulting indicator is represented against the year of pump acquisition (available for 16 of the 40 evaluated pumps). It may be observed in Fig. 4 that the relative efficiency indicator varied from 40% to 100%, indicating that some pumps operate satisfactorily while others have very poor performance, with clear consequences on the cost of electricity and the performance of the irrigation system. On the other hand, there was no correlation between the age of the pump and the relative efficiency indicator. It seems that the deterioration of the pumps occurs at age older than 12 years.

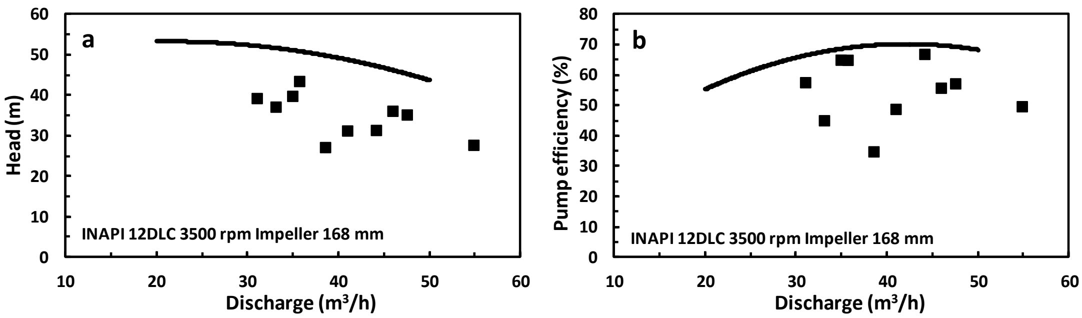

Figure 3. Head-discharge and efficiency-discharge characteristic curves and actual values for INAPI pumps in 10 farm lots of the Baixo Acaraú Irrigation District

5. Conclusions

Pumping efficiency in DIBAU farm lots is overall poor. The consequences in terms of electricity cost and irrigation system performance should be examined. An assessment of the performance of all other components of the irrigation system will follow this evaluation. Hopefully, the integrated analysis will reveal specific causes of poor performance, thus it will be possible to formulate specific recommendations for improvement. The existence of good-performing motor pumps gives hope for using benchmarking as technique for participatory learning and improvement.

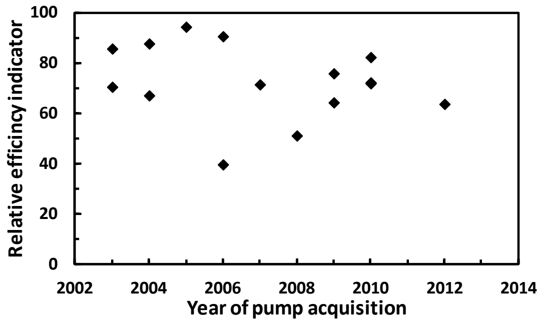

Figure 4. Ratio between the actual efficiency and the catalogue pump efficiency for the actual discharge measured in the farm lots for which the pump age was known.

ACKNOWLEDGEMENTS

We greatly appreciate the work of the team who conducted the field evaluations. We also thank the interest and kindness of the DIBAU farmers whose irrigation systems were evaluated. The study was funded by the project "Bases Científicas do Assessoramento na Melhoria da Irrigação", Programa Ciência Sem Fronteiras, 61/2011 MEC/MCTI/CAPES/CNPQ/FAPs, Brazil.

REFERENCES

Borgia, C., García-Bolaños, M., Li, L., Gómez-Macpherson, H., Comas, J., Connor, D., Mateos, L., 2013. Benchmarking for performance assessment of small and large irrigation schemes along the Senegal Valley in Mauritania. Agricultural Water Management 121: 19-26.

Burney, J.A., Naylor, R.L., Postel, S.L., 2013. The case for distributed irrigation as a development priority in sub-Saharan Africa. PNAS 110: 12513-12517.

Burney, J., Cesano, D., Russell, J., Lèvre La Rovere, E., Corral, T., Coelho, N.S., Santos, L., 2014. Climate change adaptation strategies for smallholder farmers in the Brasilian Sertão. Climatic Change 126: 45-59.

Gonçalves, F.M., Ribeiro, R.S.F., Costa, R.N.T., Burte, J.D., 2015. A management analysis tool for emancipated public irrigation areas using neural networks. Water Resources Management 29: 2393-2406.