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ORIGINAL ARTICLE

General Energy Yield in the Furrows Irrigation System

Rendimiento Energético General en el Sistema de Riego por Surcos

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ABSTRACT: The energy efficiency of irrigation systems is an aspect of great importance in all design and management processes; For this reason, an investigation was carried out in the "Tío Pedro" farm located in the municipality of Venezuela, Ciego de Ávila province during the years 2021 and 2022 with the objective of estimating the general energy yield in the furrow irrigation system. During this period, the pump unit offers the following average operating regime: pump flow rate of 61.1 L s^{-1}; pumping time of 2,8 hours and pumping head of 18.2 m. This behavior reduces a hydraulic power of 10.9 kW and a pump efficiency of 85.2%. The energy supplied in pumping was 429.4 kWh and the energy absorbed in the evaluated period was 631.9 kWh. In relation to the energy parameters of the system, an energy balance of the supply of 7,4 m was obtained; a system energy load index of 15.2 m; an energy efficiency of the pumping of 68.2% (excellent) and a general energy efficiency of the system of 34.0% (normal).

Keywords: Hydraulic Efficiency, Hydraulic Power, Energy Efficiency of Pumping.

RESUMEN: La eficiencia energética de los sistemas de riego es un aspecto de gran importancia en todos los procesos de diseño y manejo; por este motivo se desarrolló una investigación en la finca “Tío Pedro” ubicada en el municipio de Venezuela, provincia Ciego de Ávila durante los años 2021 y 2022 con el objetivo de estimar el rendimiento energético general en el sistema de riego por surcos. Durante este periodo la unidad de bombeo funcionó con el siguiente régimen de operación promedio: caudal de bombeo de 61,1 L s^{-1}; tiempo de bombeo de 2,8 horas y carga de bombeo de 18,2 m. Este comportamiento determinó una potencia hidráulica de 10,9 kW y rendimiento de la bomba de 85,2%. La energía suministrada en el bombeo fue de 429,4 kWh y la energía absorbida en el periodo evaluado de 631,9 kWh. En relación con los parámetros energéticos del sistema se obtuvo un balance energético del suministro de 7,4 m; un índice de carga energética del sistema de 15,2 m; un rendimiento energético del bombeo de 68,2% (excelente) y un rendimiento energético general del sistema de 34,0% (normal).

Palabras clave: Eficiencia hidráulica, potencia hidráulica, rendimiento energético del bombeo.

INTRODUCTION

In the current context characterized by climate change, the increase in efficiency in the use of water and energy in agriculture is of vital importance, so it is necessary to generate adaptation actions that allow adjusting the planning, operation and irrigation performance evaluation (Selim *et al.*, 2018; López-Silva *et al.*, 2019).

Irrigation scheduling is highly significant in reducing water and energy consumption in irrigation systems; as well as in the increase of crop yields; However, sometimes the producers do not grant the value of the control of energy consumption in the irrigation activity; to achieve an efficient use of energy (Cisneros-Zayas *et al.*, 2020).

The study of the energy efficiency of an irrigation network must be carried out based on the energy diagnosis of the system, which allows obtaining a vision of the current state of the network and its possibilities for improvement (Martinez-Aguilar *et al.*, 2020). The results allow us to develop a model mathematical system to simulate the conditions of the system, carry out water and energy audits of the network and adopt a series of measures that increase

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energy efficiency with the purpose of reducing energy consumption (Roselló-Tornero, 2018).

The energy efficiency of a pumping system is a measure of the efficiency with which electrical energy is converted into hydraulic energy to move fluid through the pipeline and overcome system head and is defined as the ratio of hydraulic energy delivered by the pump and the electrical energy consumed by the pump (Barreda-Trujillo, 2012).When the previous definition focuses specifically on the efficiency with which electrical energy is converted into hydraulic energy to irrigate crops; then reference is made to the concept of energy performance of an irrigation system.

The evaluations to determine the energy efficiency of an irrigation system must be supported in the decision-making process considering improvements in the water distribution system, to optimize energy consumption and economic planning (Stambouli *et al.*, 2014; Tarjuelo *et al.*, 2015; Tornés-Olivera *et al.*, 2016; 2020 ; Selim *et al.*, 2019). In this sense, the objective of this work is to determine the general energy yield in the furrow irrigation system in the Dos Amigos farm in the province of Ciego de Ávila.

MATERIALS AND METHODS

The research was carried out at the Tío Pedro farm in the municipality of Venezuela, Ciego de Ávila province, Cuba, which is located at 21°45'04" North Latitude and 78°46'45" West Longitude . The experimental area consisted of a completely randomized strip experiment with a length of 251.60 m and a variable width in correspondence with the spacing between rows according to the crop evaluated.

In this surface, 10 representative furrows were selected and subdivided into three subplots with a length of 62.90 m with the purpose of achieving greater control of the experimental variables (Figure 1). The rows evaluated were the three central rows of the four plots.

In the investigation, the crops of: black bean of the ICA PIJAO variety planted with spacing between plants of 10 cm and between rows of 60 cm for a plantation frame of 0.24 m^2 and tomato of the L-43 variety were evaluated planted with 34 cm spacing between plants and 90 cm between rows for a planting frame of 1.22 m^2. These cultivars were planted with an average furrow depth of 20 cm and the norms established for this type of soil were taken into account in accordance with the guidelines of the Ministry of Agriculture (Minag-Cuba, 2000 ; 2009). The sowing and harvest dates were those shown in Table 1.

In the study area, an open furrow irrigation system has been established, consisting of a Caprari submerged vertical centrifugal pump type T8C/7/8-71X connected to an asynchronous submerged electric motor with a 100 mm diameter coupling to the hydraulic parts; a hydraulic masonry work for the diversion of water; the main channel dug into the ground and without lining with a superficial width of 1.85 m; base width of 0.12 m; total height of 0.38 m and length of 512 m. This is used to supply water to the internal irrigation network of the farm where the experimental plot is located.

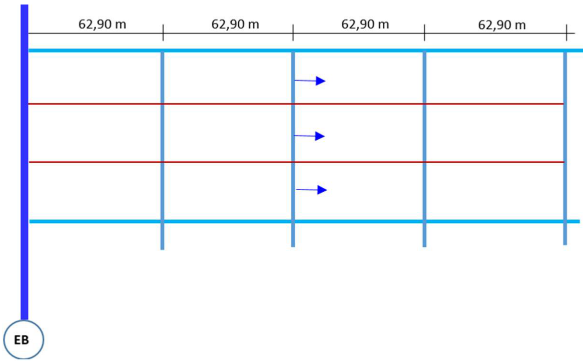

FIGURE 1. Schematic representation of the experimental area.

TABLE 1. Planting and harvest dates.

Crop	Sowing or planting date	Harvest date
Tomato	11/04/2021	02/14/2022
Bean	01/07/2022	04/24/2022

The operating flow of the pump was obtained in the discharge pipe from the measurement of the time in which the masonry work was filled for the flow diversion built next to the pump with dimensions of 3.00 m wide, 2.55 m long and 1.00 m high for a total volume of 7.65 m^3. The volumetric method according to Pérez (2022) was used from the measurement of the time in which the flow diversion work was filled by means of a digital stopwatch with a precision of 0.10 seconds.

The electrical parameters of the motor measured were the current, the voltage and the power factor with the use of the analyzer of electrical networks of the brand SPERRY DSA-500. The variables were measured in each of the irrigations carried out throughout the period and repeated five times to obtain the average value.

The total workload of the pump was obtained by applying the energy balance between two points; that is, between the surface of the water level in the well and at the outlet of the discharge pipe. In this analysis, the reference level was traced through the base of the pumping equipment. If the suction and discharge pressures are canceled because they are points where atmospheric pressure acts, the following mathematical expression is obtained to estimate the total workload of the pump:

$$H_B = \frac{v_d^2}{2g} + (Z_d - Z_a) + \Sigma h_{T_{a-d}} \quad (1)$$

Where H_B is the total working load of the pump (m); v_d the velocity in the discharge pipe (m s^{-1}); g the force of gravity (m s^{-2}); Z_a the suction height with respect to the base of the pump (m); Z_d the discharge height with respect to the base of the pump (m); $\Sigma h_{Ta\text{-}d}$ the total frictional and localized energy losses (m).

The efficiency of the motor in the pumping system was estimated from the hydraulic power of the pump and the energy losses in the system. The equations used were:

$$\eta_m = \frac{P_h}{(P_h + \rho \,.\, g \,.\, \Sigma h_{Ta-d})}100 \quad (2)$$

$$P_h = \rho \,.\, g \,.\, Q_B \,.\, H_B \quad (3)$$

Where η_m is the motor efficiency (%); P_h the hydraulic power (W); ρ the density of water (kg m^{-3}); g the acceleration due to gravity in (m s^{-2}); the total energy losses due to friction and located (m); Q_B the flow discharged by the pump (m^3 s^{-1}); H_B the total working load of the pump (m).

The efficiency of the pump was calculated based on the law of conservation of energy. In this case, the total energy in the pumping system is made up of the energy delivered by the pump to the liquid, the energy consumed by the pump, and the energy losses in the system. The following equation was used:

$$\eta_b = \frac{\eta_{em}}{\eta_m}100 \quad (4)$$

Where η_b is the efficiency of the pump (%); η_{em} the electromechanical performance of the motor-pump assembly. This performance was determined analytically from the relationship between hydraulic power and motor power as a function of motor supply voltage, electric current consumed by the motor and motor power factor.

The energy evaluation of the pumping equipment under the actual management conditions of the surface irrigation system was carried out in accordance with the criteria of the Institute for Energy Diversification (IDAE) according to Martinez (2015), which allow establishing the energy performance from the energy audits in the irrigation systems. Three energy parameters were evaluated: general energy yield, pumping energy yield and energy supply yield of the irrigation system.

The general energy yield of the furrow irrigation system was determined as the product between the energy yield of the pumping and the energy supply yield of the irrigation system. The equation used is the following:

$$\eta_{EG} = \eta_{EB} \cdot \eta_{ES} \quad (5)$$

Where η_{EG} is the general energy yield of the irrigation system (%); η_{EB} the energy efficiency of pumping (%); η_{ES} the energy yield of the irrigation system (%).

The energy yield of the pumping was defined through the division of the energy supplied in the pumping with respect to the energy absorbed in the evaluated period. The equations used were the following:

$$\eta_{EB} = \frac{E_{SB}}{E_{ABS}}100 \quad (6)$$

$$E_{SB} = \sum_{i=1}^{N_r} (P_h)_i \cdot (T_B)_i \quad (7)$$

$$E_{ABS} = \frac{\sum_{i=1}^{N_r} (P_h)_i \cdot (T_B)_i}{(\eta_b)_i \cdot (\eta_m)_i \cdot (\eta_v)_i} \quad (8)$$

Where η_{EB} is the energy efficiency of pumping (%); E_{SB} is the energy supplied in pumping (kWh); E_{ABS} the energy absorbed in the evaluated period (kWh); P_h the output hydraulic power (kW); T_B the pumping time in each irrigation event i (h); N_r the amount of irrigation performed in the crop cycle; η_b the efficiency of the pump; η_m the performance of the engine; η_v the performance of the variable speed drive.

The energy efficiency of the pumping was calculated by means of the quotient between the energy balance of the supply and the energy load index of the irrigation system. The equations used were the following:

$$\eta_{SE} = \frac{\Delta E}{ICE}100 \quad (9)$$

$$\Delta E = \frac{\sum_{i=1}^{N_r} (V_R)_i \cdot (H_B)_i}{V_T} \quad (10)$$

$$ICE = \frac{\sum_{i=1}^{N_r} (V_B)_i \cdot (H_B)_i}{V_T} \quad (11)$$

$$(V_R)_i = M_n \,.\, (T_B)_i \quad (12)$$

$$(V_B)_i = (Q_B)_i \,.\, (T_B)_i \quad (13)$$

$$V_T = \sum_{i=1}^{N_r} (V_B)_i + V_{LL} \quad (14)$$

where η_{SE} is the yield of the energy supply of the irrigation system (%); ΔE the energy balance of the supply (m); ICE the energy load index of the irrigation system (m); $(V_R)_i$ the volume of water required in each irrigation shift i (m^3); M_n the net irrigation norm according to Pacheco *et al.* (2007); $(V_B)_i$ the volume of water pumped in each irrigation shift i (m^3); V_{LL} the volume of water contributed by the rains in the crop cycle (m^3); V_T the total volume of water received by the crop in the vegetative cycle (m^3).

The evaluation of the general energy yield of the system (η_{EG}) and the energy yield of the pumping (η_{EB}) was carried out according to IDAE criteria Martínez (2015), as shown in Table 2.

RESULTS AND DISCUSSION

Table 3 and Table 4 show the results of the flow discharged by the pump and the performance of the pump for a value of 1450 revolutions per minute for tomato and bean crops. In the case of tomato cultivation, the average values of the variables specified above had the following behavior for 15 irrigation events: flow discharged by the pump of 60.1 L s^{1}; pumping time 2.9 h; total working load of the pump of 17.9 m; 10.5 kW output hydraulic powers and 82.1% pump efficiency.

Similarly, in the bean crop, the mean values of the previously indicated variables performed as follows for 14 irrigation events: flow discharged by the pump of 62.0 Ls^{-1}; pumping time 2.6 h; total working load of the pump of 18.4 m; 11.2 kW output hydraulic power and 88.2% pump efficiency.

In the irrigation of both crops, a value of the pump performance higher than 82.0% was obtained, which is why it is evaluated as acceptable; because a performance greater than 75% is good, while a performance less than 50% is deficient; although this parameter depends on the type of pump, its design, operating conditions and other factors. The results obtained by Ascencios *et al.*(2020) and Pérez (2022) in investigations carried out with the use of pumping with photovoltaic solar energy and for the irrigation of a subterranean drip irrigation system warn about the need for the pumps to operate with high efficiency to contribute to energy savings.

In order to ensure that the system works properly, it is advisable to carry out the tests under real operating conditions of the pumping equipment, which can be obtained from specific tests that include the measurement of flow, pressure and power at different operating points (Burbano & Narváez, 2021; Rojas-Suarez *et al.*, 2021).

Table 5 shows the values of the energy supplied in the pumping, the energy absorbed in the evaluated period and the energy yield of the pumping for the tomato and bean crops. The average results achieved were: energy supplied in the pumping of 429.4 kWh; absorbed energy of 631.9 kWh and energy efficiency of pumping of 68.2%, which is evaluated as excellent according to Martinez (2015).

Table 6 shows the values of the average volume of water pumped in each irrigation shift, the energy balance of the supply, the energy load index of the irrigation system, the energy yield of the irrigation system and the general energy yield of the irrigation system for tomato and bean crops. The results showed the following average behavior: pumped water volume of 605.7 m^3; energy balance of the supply of 7.4 m; energy load index of the irrigation system of 15.2 m; energy yield of the irrigation system of 49.2% and general energy yield of the irrigation system of 34.0%, which indicates, according to Martínez (2015), a

TABLE 2. Evaluation criteria for energy indices.

Performance	η_{EB} (%)	η_{EG} (%)
Excellent	> 65	> 50
Good	60 - 65	40 - 50
Normal	50 - 60	30 - 40
Acceptable	45 - 50	25 - 30
Not acceptable	< 45	< 25

TABLE 3. Flow rates and performance of the pump in tomato cultivation.

Date	Q_B (Ls^{-1})	η_b (%)
11/04/2021	60.9	85.8
11/11/2021	59.3	80.4
11/18/2021	61.8	86.6
11/25/2021	61.4	84.7
12/02/2021	59.0	78.9
12/09/2021	60.0	84.4
12/16/2021	58.7	79.4
12/23/2021	59.1	79.5
06/01/2022	59.4	81.8
01/13/2022	60.3	80.6
01/20/2022	61.2	84.3
01/00/2022	59.5	80.5
02/02/2022	59.8	80.0
02/09/2022	61.2	82.6
02/16/2022	59.7	82.1
Average	60.1	82.1

TABLE 4. Flow rates and performance of the pump in the bean crop.

Date	Q_B (Ls^{-1})	η_b (%)
01/07/2022	62.3	88.9
01/14/2022	62.6	89.7
01/21/2022	62.1	89.0
01/28/2022	62.2	88.7
02/04/2022	60.9	86.0
02/11/2022	61.7	90.0
02/18/2022	61.5	87.8
03/10/2022	62.1	89.7
03/17/2022	60.6	85.2
03/24/2022	62.4	89.2
03/31/2022	61.9	86.5
04/07/2022	62.5	88.7
04/14/2016	62.2	87.1
04/18/2016	63.1	89.9
Average	62.0	88.2

TABLE 5. Energy efficiency of pumping.

Crop	E_{SB} (kWh)	E_{ABS} (kWh)	η_{BE} (%)
Tomato	449.6	684.4	65.7
Bean	409.2	579.3	70.7
Average	429.4	631.9	68.2

TABLE 6. General energy performance of the irrigation system.

Crop	V_B (m^3)	ΔE (m)	ICE (m)	η_{ES} (%)	η_{GA} (%)
Tomato	616.3	7.9	16.1	49.3	32.4
Bean	585.0	8.5	16.3	52.0	36.8
Average	605.7	7.4	15.2	49.2	34.0

normal performance, which can be improved with operation and maintenance that the pumping of groundwater for furrow irrigation in tomato and bean crops in red ferralitic soils with flows in the range of 59.0 and 62.6 L s^{-1} and average values: irrigation events 15; pumping time 2.8 h; total workload of the pump of 18.2 m and a volume of water pumped of 605.7 m^3 provides an excellent energy efficiency of pumping with a value of 68.2% and a general energy efficiency of the irrigation system evaluated as normal with a 34.0%, which is feasible to improve if adequate measures are taken for operation and maintenance.

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REFERENCES

ASCENCIOS, D.; MEZA, K.; LLUEN, J.; SIMON, G.: “Calibración, validación y automatización del sistema de riego por goteo subterráneo usando un microcontrolador Arduino”, *Revista de Investigaciones Altoandinas*, 22(1): 95-105, 2020, ISSN: 2313-2957, Publisher: Universidad Nacional del Altiplano.

BARREDA-TRUJILLO, Á.U.: “Método práctico de obtención de potencia y eficiencias de unidades de bombeo en operación”, *Ingeniería hidráulica y ambiental*, 33(3): 86-97, 2012, ISSN: 1680-0338.

BURBANO, V.; NARVÁEZ, R.: “Evaluación de la pre factibilidad para la generación de energía eléctrica mediante la sinergia entre las energías eólica y almacenamiento por bombeo de agua en la isla San Cristóbal-Galápagos”, *Revista Técnica" energía"*, 17(2): 29-43, 2021, ISSN: 2602-8492.

CISNEROS-ZAYAS, E.; GONZÁLEZ-ROBAINA, F.; HERRERA-PUEBLA, J.; DUARTE-DÍAZ, C.; MATOS-CREMÉ, H.: “Influencia de la programación del riego en los consumos energéticos”, *Revista Ingeniería Agrícola*, 10(4): 3-11, 2020, ISSN: 2227-8761.

LÓPEZ-SILVA, M.; CARMENATES-HERNÁNDEZ, D.; MUJICA-CERVANTES, A.; PANEQUE-RONDON, P.: “Criterios de eficiencia para la evaluación del riego por aspersión”, *Revista Ciencias Técnicas Agropecuarias*, 28(3): 1-8, 2019, ISSN: ISSN: 1010-2760, e-ISSN: 2071-0054, Publisher: Universidad Agraria de La Habana.

MARTÍNEZ, M.A.: *Estrategia para la evaluación agronómica, hidráulica y energética en jardinería. Aplicación a la gestión de jardines públicos*, *[en línea]*, Ed. Editorial: UPV, primera ed., Valencia, España, 120, Publisher: Universitat Politècnica de València, Publisher: Universitat Politècnica de València, 2015, *Disponible en:* https://riunet.upv.es/handle/10251/53389?show=full.

MARTÍNEZ-AGUILAR, F.B.; GUEVARA-HERNÁNDEZ, F.; ARIAS, L.O.; ALEJANDRO, M.; RODRÍGUEZ LARRAMENDI, L.A.; PINTO-RUIZ, R.; AGUILAR-JIMÉNEZ, C.E.: “Caracterización de productores de maíz e indicadores de sustentabilidad en Chiapas”, *Revista mexicana de Ciencias Agrícolas*, 11(5): 1031-1042, 2020, ISSN: 2007-0934, Publisher: Instituto Nacional de Investigaciones Forestales, Agrícolas y Pecuarias.

MINAG-CUBA: “Instructivo Técnico para el cultivo del frijol. Lista oficial de variedades comerciales”, La Habana, Cuba, 2000.

MINAG-CUBA: *Instructivo Técnico para el cultivo del frijol*, Ed. Editorial CIDA, Publisher: Minag, La Habana, Cuba, 2009.

PACHECO, J.; ALONSO, N.; PUJOL, P.; CAMEJO, L.E.: *Riego y Drenaje*, Editorial Félix Varela, 2da ed., La Habana, Cuba, 2007.

PÉREZ, V.D.A.: “Diseño del sistema de agua potable por bombeo fotovoltaico para el Cantón Alta Vista, Aldea El Rodeo, San Marcos”, *Revista de Investigación Proyección Científica*, 4(1): 71-88, 2022, ISSN: 2957-8582, e-ISSN: 2310-2799.

ROJAS-SUAREZ, J.P.; VERGEL-ORTEGA, M.; ORJUELA-ABRIL, S.: “Investigaciones con CFD aplicadas a bombas centrífugas”, *Revista Boletín Redipe*, 10(9): 515-525, 2021, ISSN: 2256-1536.

ROSELLÓ-TORNERO, J.: *Estudio de la eficiencia energética de la red de riego abastecida por el cabezal número uno en el término de Nules*, *[en línea]*, Ed. Editorial: UPV, Valencia, España, Publisher: Universitat Politècnica de València p., publisher: Universitat Politècnica de València, 2018, *Disponible en:* https://riunet.upv.es/handle/10251/102984.

SELIM, T.; KARLSSON, L.; BOUKSILA, F.; BEN, A.S.; PERSSON, M.: “Evaluation of Different Irrigation Treatments with Saline Water in a Future Climate in Tunisia”, *Irrigation and Drainage*, 67(4), 2018, ISSN: 1531-0353, DOI: https://doi.org/10.1002/ird.2307.

SELIM, T.; KARLSSON, L.; BOUKSILA, F.; BEN-SLIMANE, A.; PERSSON, M.: "Evaluation of different irrigation treatments with saline water in a future climate in Tunisia", *Irrigation and Drainage*, 68(2): 281-296, 2019, ISSN: 1531-0353, Publisher: Wiley Online Library.

STAMBOULI, T.; FACI, J.; ZAPATA, N.: "Water and energy management in an automated irrigation district", *Agricultural Water Management*, 142: 66-76, 2014, ISSN: 0378-3774, Publisher: Elsevier.

TARJUELO, J.M.; RODRIGUEZ-DIAZ, J.A.; ABADÍA, R.; CAMACHO, E.; ROCAMORA, C.; MORENO, M.A.: "Efficient water and energy use in irrigation modernization: Lessons from Spanish case studies", *Agricultural Water Management*, 162: 67-77, 2015, ISSN: 0378-3774, Publisher: Elsevier.

TORNÉS-OLIVERA, N.; AJAYI, O.O.; GÓMEZ-MASJUAN, Y.; GUERRERO-ALEGA, A.: "Eficiencia de aplicación máxima del agua y longitud del surco en función de los caudales", *Revista Ciencias Técnicas Agropecuarias*, 25(1): 23-27, 2016, ISSN: ISSN: 1010-2760, e-ISSN: 2071-0054, Publisher: Universidad Agraria de La Habana.

TORNÉS-OLIVERA, N.; GÓMEZ-MASJUAN, Y.; MYOR-ROBLES, E.; BROWN-MANRIQUE, O.: "Determinación de la eficiencia hídrica y energética en el riego localizado, bajo condiciones protegidas", *Revista Ciencias Técnicas Agropecuarias*, 29(1): 46-55, 2020, ISSN: ISSN: 1010-2760, e-ISSN: 2071-0054, Publisher: Universidad Agraria de La Habana.

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