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Efficiency conduction in irrigation systems of rice companies

Camilo Bonet Pérez[1,*], Héctor Moreno Guerra[2], Pedro Guerrero Posada[1], Raidel Vidal González [2], Dania Rodríguez Correa[1], Eduardo Fernández[2], Bárbara Mola Fines[1], Raidel Vidal González[2] Fernando R. Puente Borrero[2]

1. Agricultural Engineering Research Institute, Camaguey Subsidiary, Cuba 2. Cuba's "Southern Guibaro" Grain Agriculture Industry Company
*Corresponding author.
E-mail address: esp.riego.iagric@dlg.cmg.minag.gob.cu

Abstract: The determination of the conduction efficiency in the production units of rice-producing companies is a working tool for technicians and officials involved in the operation of irrigation systems, as it provides greater precision for the implementation of water demands and control of the water used, and accurate information on the technical condition of the canals, which is the basis for the programming of maintenance and repairs. In order to determine the behaviour of the conduction efficiency of a rice irrigation system under production conditions and compare the results with the indicators traditionally used, a study was carried out on the irrigation system supplied by the P-4 canal of the Unidad Básica de Producción Cooperativa (UBPC) Sur de Jíbaro, belonging to the company of the same name in the province of Sancti Spiritus. The hydro-technical works located at the regulation points, which had been previously calibrated, and the section and velocity method in cases where these works were not available, were used to determine the flow rate. The results indicate a general conduction efficiency of the system of 42%, a value that differs considerably from that reflected in the documents governing this activity, with the greatest losses in the tertiary canals in which 57% efficiency was obtained.
Key words: efficient water use; hydrometry; water management; hydrometry constructions

1 Introduction

According to Herrera et al. (2013), the current water use situation in Cuba, cited by Duarte et al. (2017), indicates that approximately 60% of available water is used for agricultural production each year. More than 90% of the total water consumed by the Ministry of Agriculture is used for crop irrigation, with an average total efficiency of 65% (Official Gazette of the Republic of Cuba, 2015).

Rice cultivation is the largest water user in the country, therefore it is necessary to effectively utilize this resource.

According to Duarte et al. (2015), the net standard total amount of this crop exceeds 10,000 cubic meters per hectare. Therefore, the irrigation system of the rice company uses a large amount of water, causing huge losses; By analyzing the total irrigation standards, it can be seen that the planned consumption is very high.

They mentioned the research of FAO (2017), and the main reasons for the water loss of the canal include: the transmission loss from the source to the seeding area, the technical condition of the canal, non-compliance with system maintenance, the lack of land leveling, and the lack of agricultural technology for water management during farming.

The impact of climate change is predicted to increase crop demand for water due to the increased frequency and intensity of drought periods (Planos et al., 2013; Duarte et al., 2017).

During the operation of irrigation systems in large rice companies, water loss can occur through channel networks. Technicians and professionals involved in this activity must understand the unique characteristics of their irrigation systems, which will enable them to be more objective in executing water demands of the National Institute of Water Resources (INRH), as well as the maintenance and repair planning of the irrigation system.

According to Fontova and García (2001), it is inappropriate to use the assumed standard of the total conduction efficiency in the operation of these irrigation systems throughout history. Here are some examples (Table 1).

Table 1. Comprehensive efficiency of crop irrigation systems

System type	Efficiency (%)	
	A	B
Engineering system	68	70
Semi engineering system	63	60
Traditional systems	45	40

These global efficiency values include field water efficiency, which means higher conduction efficiency values. The quoted values may be high or low, but the fact is that by using a common value for all fields, the differences in the length of different types of ditches connected to irrigation fields have been omitted, and the length differences of these ditches are significant.

Water management in irrigation and drainage systems for rice cultivation requires proper coordination between the supply of water to the fields and the evacuation of water from the fields. In this regard, Herrera et al. (2016) refer to the importance of the extraction of excess water in case of rainfall, whose frequency and magnitude are impossible to forecast (Bonet, 2015).

Understanding the total water consumption of crops is important for determining water productivity and aquatic yield ratio (González et al., 2013, 2014). In order to achieve this balance, it is necessary to determine the water conduction efficiency in the canal, which is achieved by applying the principles of operational hydrological measurement (Cu et al., 2017). The purpose of this study is to determine the field conduction efficiency in rice crop irrigation systems and compare the results with reference values.

2 Methods

This study was conducted in the basic cooperative production unit of the Food Agriculture Industry Company of the same name in Sancti Spiritus Province, Cuba, called "South Guibaro". The study selected the area provided by the P-4 Canal, which is related to the semi engineering irrigation system. This is an excavated canal without lining; The system has the parameters shown in Table 2.

Table 2. Technical parameters of irrigation system

Category	Longitude (m)	Q Design (L/S) No	Water conservancy project
Primary	13610	3600	11
Secondary	9900	600	44
Tertiary	48200	180	

The system has a main channel (P-4) with 11 sub channels, each providing 1 four-field block and 44 third-channels (Table 3).

Table 3. Irrigation area size

Grid	Size field (m)	Field area (ha)	Block area (ha)	Total area (ha)
A, B, C, D, E F, H, I	1350 x 300	40,5	162,0	1296,0
A´	1800 x 300	54,0	216,0	216,0
G	950 x 300	28,5	114,0	114,0

At each delivery point leading to the secondary canal, the P-4 canal has a distribution project with rectangular gates that have been calibrated by placing scales upstream and downstream of the project, enabling expenditure to be measured based on differences in the height and flow of the gates; These works were previously validated using the hydrological measurement windmill method, with a difference of less than 8%, which enables them to be used in the work of this study.

Figure 1 shows the overall schematic diagram of the P-4 canal irrigation system.

In order to determine the conduction efficiency of the P-4 channel, a guarantee of 1,000 L/s was coordinated with INRH at the delivery point at the beginning of the channel, referring to the four allocation points corresponding to grid C, F.I, and J. Delivery to the secondary channel on the route has been closed. Therefore, the difference between the expenditure measured at the end of the channel and the expenditure entering the channel is entirely due to losses caused by different reasons.

Expenditure is measured using the calibrated hydro-technical works according to Aliexpiorov et al. (1986); León (2002) determined the specific loss based on this information and calculated the cost of the remaining allocation points of the main channel based on the obtained results, which is the basis for determining the entire length of the channel and the transmission efficiency of each part.

Visual inspection showed that the length and technical status of the secondary channels were the same, and they were supported on the same type of soil. Therefore, the S-6 channel serving Zone E (Fields 21 to 24) was chosen as the representative of the system, as it is located in the center of the area and uses the same procedure to determine conduction efficiency. For the third level canal, following the same standards, a 1,350 meter long canal was selected as the most representative measure. Considering that there were no engineering projects at the end of the canal, the section and velocity methods were used, and the following procedure was followed: the area was measured using a tape measure and wooden stakes based on the geometric shape of the canal section (trapezoid); The velocity of water is measured using a float, and this program is suitable for small cross-section channels where the surface velocity represents the velocity of water flow, just like Herrera et al.'s current research (2013) and ISO 748:2007 (2014). Time is measured using a stopwatch, repeated three times for error correction. A 10 meter long straight line and a uniform cross-section were selected in advance, and the floating object was placed 2 meters in front of the starting point to obtain a stable speed (Condori, 2012).

Equation used:

$$Q=A*v \quad (1)$$

$$Efc=9(Qs/Qe)\ 100 \quad (2)$$

$$Pe=P/L \quad (3)$$

$$P=Qs-Qe \quad (4)$$

$$Q\ (ant)=Qs+P \quad (5)$$

$$Efc\ (ant)=[Q(ant)/Qe100] \quad (6)$$

$$Efc(campo)=(Efc(p)*Efc(s)*Efc\ (t) \quad (7)$$

Among them:

A Section area (m^2); v Water velocity (m/s); *Efc* Conduction efficiency (%); *Qs* Outflow from the evaluated section (L/s); Qe Inflow to the evaluated section (L/s); Pe Specific losses (L/s/m); PP losses (L/s); L Length of the evaluated section (m); Q (ant) Flow at the point before the evaluated section (L/s); Efc (ant) Conduction efficiency at the point before the evaluated section (%); Efc (field) Efficiency of conduction to the field (%).

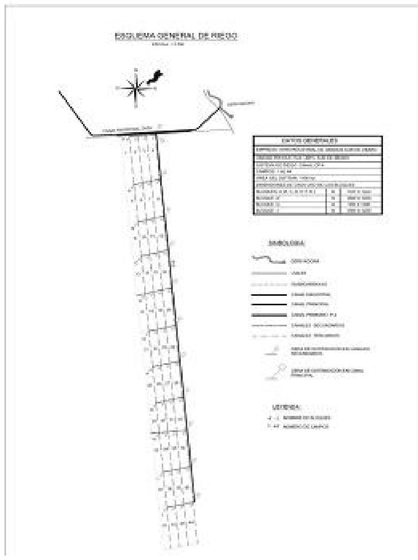

Fig. 1. Schematic diagram of irrigation system

3 Results and discussion

Table 4 shows the conduction efficiency values of the main channel obtained at the selected points of the P-4 channel.

Table 4. Conduction efficiency of P-4 channel control points

Control point	Q (L/s)	Efc (%)
INRH 1000 delivery point		
1	880	88
2	710	71
3	650	65
4	600	60

These results calculate the specific losses shown in Table 5.

Table 5. Specific losses of major channels

Section	Qe (L/s)	Qs (L/s)	Efc (%)	Pe (L/s/m)
4	650	600	92	0,037
3	710	650	91	0,016
2	880	710	81	0,042
1	1000	880	88	0,026

Considering the distance from other allocation points, the conduction efficiency of the unevaluated P-4 channel allocation points was estimated based on the specific losses of each road section (Table 6).

Table 6. Conduction efficiency of allocation points compared to delivery points

Distribution points	Pe (L/s/m)	L (m)	P (L/s)	Q (L/s)	Efc (%)
Block H	0,016	1350	22	672	67
Block G	0,016	950	15	687	68
Block E	0,042	1350	57	767	77
Block D	0,042	1350	57	824	82
Block B	0,026	1350	35	915	91
Block A	0,026	1350	35	950	95
Block A´	0,026	1800	47	997	100

In the P-4 Canal, the key section is No. 2, with a specific loss of 42 L/S/km, which is due to the severe deterioration of some canal sections in this section.

In the second channel, the expenditure values of the inlet and outlet were measured, and the results were 180 and 144 L/s respectively, to determine a specific loss value of 80% of the conduction efficiency and 0.040 L/s/m of the total channel length. The distance between the tertiary canals is 300 meters, so the conduction efficiency of each section of the secondary canal was calculated, and the results are shown in Table 7.

Table 7. Conduction efficiency of secondary channels

<table>
<tr><th>Section</th><th>Pe (L/s/m)</th><th>D (m)</th><th>P (L/s)</th><th>Q (L/s)</th><th>Efc (%)</th></tr>
<tr><td>T - 4</td><td rowspan="4">0,040</td><td>300</td><td rowspan="4">12</td><td>144</td><td>80</td></tr>
<tr><td>T - 3</td><td>300</td><td>156</td><td>86</td></tr>
<tr><td>T - 2</td><td>300</td><td>168</td><td>93</td></tr>
<tr><td>T - 1</td><td></td><td>180</td><td>100</td></tr>
</table>

In this case, the first section was not calculated because the first tertiary channel started at the beginning of the secondary channel and therefore there were no losses up to the secondary channel.

In the tertiary channel, the values of flow at the inlet and outlet were 150 and 85 L/s respectively, resulting in a conduction efficiency of 57%.

Once the territorial distribution of the system and each of the fields linked to it were known, the total conduction efficiency up to the level of each field was determined (Table 8).

Table 8. Total drive efficiency range (%)

Efficiency range (%)	No.	Fields Area (ha）	%
>50	6	270,0	14,9
45 - 49	7	310,5	17,2
40 - 44	9	364,5	20,2
35 - 39	10	393,0	21,8
< 35	12	468,0	25,9

The results show general conduction efficiency values in relation to the INRH delivery point ranging between 57% and 27%, with an average of 42%, which are characteristics of these irrigation systems according to García et al. (1985) and Minag (2005). In the system evaluated, 67.2% of the total number of canals correspond to tertiary canals, and in these the highest conduction losses occur, with an average conduction efficiency of 57% and specific losses of 0.050 L/s/m. The results of the conduction efficiency determined differ considerably from the indicators used for rice irrigation systems. The low efficiency values in the tertiary canals are due to their instability, since they must be reconstructed frequently, which means that the bottom and slopes are not compacted. And due to the lack of engineering to transport water to the fields, they are manipulated by irrigators. Most of the water lost in the tertiary canal remains in the rice fields, but its distribution is uneven.

Considering the value used as an indicator, the conduction efficiency of the irrigation system exceeds 60%, which is significantly different from the average value obtained. Compared to the average values used, these differences reiterate the importance of their determination under the specific conditions of each system (Basan, 2008).

The research results conducted shows that it is possible to obtain information on conduction efficiency on a production scale, with an error of less than 10% based on the preparation of the personnel responsible for reading.

4 Conclusion

The field conduction efficiency varies between 27% and 57%, which is significantly different from the semi-engineered irrigation system recommended in the literature (60-63%), with the highest losses occurring in tertiary canals.

Conflicts of interest

The author declares no conflicts of interest regarding the publication of this paper.

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