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Improvement's energy used in sprinkler irrigation systems

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Abstract: The effects of the climatic change in the agricultural sector are more perceptible each day, this is reflected basically through the periods of drought that are increased in frequency and intensity. This reality forces us to carry out an efficient use of the available water; the inadequate water use pumped for the irrigation implies the low efficiency of the electric power for this activity. With the objective of valuing the effectiveness of the energy used in this activity in practice, a pilot study was conducted in Victoria II belonging to the Camagüey Agrarian enterprise. The electric power consumption in the irrigation was controlled in all the irrigation systems of the productive unit during the campaign of the cultivation of the bean in the year 2017, the productivity of the energy used in the irrigation in all irrigation systems of the technologies of pivot machines and sprinkler irrigation systems was determined, the obtained values were compared taking like reference the most favorable result. The evaluations demonstrated that during the cycle of the cultivation, losses take place in the use of the water due to the imperfect irrigation programming and low uniformity of distribution of the water, which is reflected in the low productivity of irrigation water and energy together with the concern about planting. This shows that the efficiency index of pivot machine is only 76%, and the efficiency index of sprinkler system is 63%.
Key words: productivity of the water; pumping; electricity; agricultural yield

1 Introduction

The increasingly serious problems in the supply of water for different purposes in the world, especially irrigation water, make effective use of water a priority for the agricultural sector (Falkenmark and Vincent, 2005).

One of the biggest problems facing mankind is the lack of food, energy and water. This has led to new irrigation technologies aimed at improving water efficiency and reducing energy consumption. (Alonso, 2006).

Due to climate change, our natural resources are affected, including water. 70% of available water is used for agriculture. From 1996 to 2030, irrigation land will increase by 27%, and irrigation water will only increase by 12% in the same period.

Chipana and Osorio (2007) said that in many countries, irrigation is an art as old as civilization, but for human beings, irrigation is a science of survival. Therefore, we must adapt to the new situation, urgently need to improve the use efficiency of water and energy, and increase the yield of irrigated crops.

At present, we are facing a serious water crisis, affected by climate change, resulting in drought or temporary floods. Climate change is affecting global rainfall patterns (Bueno de Mezquita, 2003). Cuba cannot avoid climate change, and studies of its impact on water supply suggest that drought conditions may increase (González, 2004).

Various researchers have studied the impact of water on crop yield in this regard. González et al. (2016), reported the differences between crops and climate variability under Cuban conditions.

Irrigation efficiency should be related not only to water use, but also to the use of energy for pumping (Martínez, 2017).

Cuba's agricultural irrigation is to a large extent realized by pumping water. For this reason, the energy used is basically electricity provided by the national power system, which comes from thermal power plants with large fuel consumption. Therefore, it is expected that the energy used in this activity will be reflected in satisfactory production results.

The UBPC Victoria II production unit under Minag, the Camaguey Agriculture Company of the Ministry of Agriculture of Camaguey Province has important irrigation infrastructure. However, the production achievements in recent years show that the water productivity is low, which affects the energy efficiency.

This is why the purpose of this work is to assess the energy efficiency of UBPC Victoria II irrigation activities.

2 Methods

Taking UBPC Victoria II belonging to Camaguey Agriculture Company as a reference, its basic activity is to produce meat, vegetables and grains. The agricultural area of this UBPC is 210.0 hectares, and the irrigation area is 157.1 hectares. According to the irrigation technology, it is divided as follows: central pivot machinery (74.4 hectares); sprinkler irrigation (82.7 hectares).

The main soils are classified as typical reddish brown and dark unsaponifiable plastics, and their hydro physical properties are summarized in Table 1 (Montejo, 2007).

Table 1. Water physical properties of main soil

Table 1A. Typical reddish brown

Pr. (cm)	DA (g cm^{-3})	P (%)	CC (% bss)	CM (% bss)	LP (% bss)	Vi (mm h^{-1})
00 – 10	1,26	52,4	31,4	18,5	29,7	21
10 – 20	1,26	52,4	30,0	17,6	28,3	21
20 – 30	1,26	52,4	34,9	20,5	32,9	21
30 – 40	1,42	47,1	31,3	18,4	33,3	21
40 - 50	1,42	47,2	27,4	16,1	29,1	21

Table 1B. Dark unsaponifiable plastics

	DA (g cm^{-3})	P (%)	CC (% bss)	CM (% bss)	LP (% bss)	Vi (mm h^{-1})
00 – 10	0,95	63,0	48,3	28,4	36,7	1,4
10 – 20	1,00	61,0	48,3	28,4	38,6	1,4
20 – 30	1,06	99,7	49,6	29,2	42,0	1,4
30 – 40	1,06	60,7	49,6	29,2	42,0	1,4
40 - 50	1,00	60,0	50,0	29,2	43,2	1,4

Caption: Pr indicates depth; DA indicates apparent density; P indicates porosity; CC indicates site capability; CM indicates wilting coefficient; Vi indicates Infiltration velocity

The irrigation system of UBPC Victoria II includes a main pump station, which supplies a regulating reservoir. Water from the reservoir reaches the irrigation area by gravity. Nine pump stations supply irrigation machinery and sprinkler irrigation system, that is, there are two pumping operations from the water supply source to the irrigation area.

Table 2 and Fig.1 show the components of infrastructure that can be used for irrigation activities.

Table 2. Infrastructure for irrigation activities

Description	Quantity
Electric pivot machines	6
Sprinkler system	3
Electric pump station	10

Fig. 1. Characteristics of available irrigation infrastructure

The characteristics of the pump station are as follows (Table 3):

Table 3. Pump station parameters

Pumping station	Flow capacity (L/s)	Load (m)
Principal	75	22
Pivot 1	16	34
Pivot 2	16	35
Pivot 3, 4, 5	16	36
Pivot 6	16	37

S/R sprinkler 2A	68	46
S/R sprinkler 2B	45	39
S/R sprinkler of La Isla	40	47

In order to determine the efficiency of the irrigation process, the irrigation quality was evaluated (ISO 11545:2001, 2007). According to ISO 11545:2009 (2011) for irrigation machinery and ISO 15886-3 (2004) for sprinkler system, the irrigation uniformity is determined according to the equations of Heermann and Hein in pivot machinery. The irrigation behavior and production results of legumes in 2017 were monitored, because legumes are the most representative crops in the production units, which enables the assessment of all irrigation systems to be included.

The energy consumption of this activity was calculated taking into account the number of times of irrigation, the irrigation time applied according to the irrigation rules, and the pumping and reverse irrigation time used in the production process of the whole soybean planting cycle. By linking the energy consumption of each system with the agricultural output obtained, the energy productivity for irrigation is obtained.

When calculating the energy efficiency of each irrigation system, the best results of each irrigation technology are referred to, and these results are compared with those of other irrigation systems.

Soil moisture is monitored by a time dormant reflectometer (TDR), which has been well applied in similar studies conducted by López et al. (2017), the wind speed was determined when using a digital anemometer for assessment.

3 Results and discussion

The application of water according to the water demand of crops is closely related to the characteristics of the irrigation technology to be used (Placeres etal., 2013; Cisneros etal., 2014).

Fig. 2 shows the evaluation process of these two irrigation technologies, and the results are shown in Table 4.

Fig. 2. Irrigation quality assessment

Table 4. Average results of irrigation quality assessment

		Irrigation technology	
Parameter	U.M.	Pivot machine	Sprinkler irrigation
Discharge efficiency	%	72	64
Distribution uniformity	%	68	56

In all cases, the values obtained according to Doorenbos and Kassam (1980) are very low, which is due to the great influence of wind, because the values are between 2.5 and 3.2 m/s during the irrigation time.

Soil moisture control shows that 82% of all samples collected are on the pivot machine, 78% are in the sprinkler system, and the humidity is kept within the appropriate range between the field capacity and the soil production limit.

Fig. 3 shows the results of the impact of irrigation on the yield of legumes in 2017.

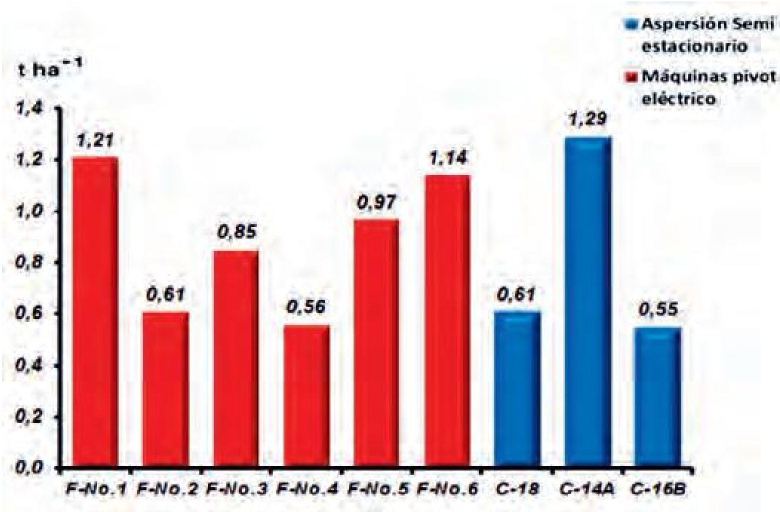

Fig. 3. Agricultural yield of legumes

The evaluation of the results shows that:

• Compared with the average value of planting this crop in the country, agricultural production is low, more than 1.5 tons/hectare.

• The results obtained under the same soil conditions and irrigation technology vary greatly.

The interpretation of these values shows that there are deficiencies related to low irrigation quality and humidity control in irrigation activities. However, there are some examples, such as Pivot 3, where the irrigation efficiency is the highest but the optimal yield is not obtained. This shows that no matter how inadequate the irrigation is, there are other external factors reflected in the production results, including: soil preparation quality, agricultural technical work, nutrition, plant protection, population, planting and excessive water (González et al., 2016; Herrera et al., 2016).

Regarding the relationship between irrigation and other agricultural technology work, Bonet et al. (2013) said that coordinated action must be taken on all factors affecting crop yield to achieve effective use of irrigation water. Cisneros et al. (2013) suggested implementing an irrigation consulting system as a way to achieve these goals under production conditions.

It is important to consider these factors because they indirectly affect the efficiency of irrigation energy use by affecting agricultural output.

According to the production results, the productivity of irrigation energy is determined (the energy consumed to produce one ton of soybean in irrigation activities). Table 5 shows the results obtained. The values of these two technologies are very dispersed, which indicates that the energy used in irrigation activities is improper (Lopez et al., 2017a) and (López et al., 2017b).

Table 5. Irrigation energy productivity

Irrigation system	Irrigation energy productivity (kWh/t)
Pivot 1	939
Pivot 2	1402

Pivot 3	1336
Pivot 4	2028
Pivot 5	1171
Pivot 6	996
Sprinkler 2A	1726
Sprinkler 2B	816
Sprinkler of La Isla	1914

The best energy productivity results in irrigation correspond to Pivot 1 and Sprinkler 2B, and the energy efficiency of each irrigation system is determined according to these results (Table 6).

Table 6. Irrigation energy efficiency

Irrigation system	Irrigation energy efficiency (%)
PIVOT	
Pivot 1	100
Pivot 2	67
Pivot 3	70
Pivot 4	46
Pivot 5	80
Pivot 6	94
Summary	76
SPRINKLER	
Sprinkler 2B	100
Sprinkler 2A	47
Sprinkler of La Isla	42
Summary	63

The average results of pivot machinery and sprinkler irrigation systems were 76% and 63% respectively, which were very low.

The values of 939 and 816 kWh/t obtained in the irrigation technology using rotating machinery and sprinkler irrigation system have not yet reached the optimal level, which indicates that under the same soil climate conditions, they can be far higher than the average values being achieved. The deviation values of 24% and 37% of the energy used in the fulcrum machine and sprinkler irrigation system indicate that it is possible to irrigate more areas and obtain higher yield if these energies are used more effectively.

In short, the deficiencies in production activities are reflected in the low energy efficiency of irrigation activities. This is a very important factor considering the large use of electricity in the pumping irrigation areas of the country, which usually do not receive the necessary attention.

4 Conclusion

• The energy efficiency of UBPC Victoria II pumping irrigation is relatively low, with an average of 76% and 63%, while the production units themselves have achieved the best results in terms of sprinkler irrigation machinery and sprinkler irrigation system technology, respectively 76% and 63%.

• Energy efficiency can be improved through proper management of irrigation systems.

Conflicts of interest

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

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