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Automatic evaluation of sprinkler irrigation systems

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Abstract

One of the problems of irrigation is the high demand of water. On occasion, water supply may not be available, or even with availability, water should be preserved. Allied to this, the lack of monitoring and proper management of systems may provide low uniformity and low efficiency irrigation. This study aims to develop and test a device that can evaluate irrigation systems having as parameters the mean depth and coefficient of uniformity application in an automatized and easy way. Sensors were tested to take readings of water level. The sensor set was built with catch cans, so it was able to collect data for system evaluation. The obtained data were compared with those obtained by measuring the volume in the catch cans with the aid of a beaker. Data were submitted to statistical tests for comparison of means. The device was suitable for use under field conditions showing better results with larger irrigation depths. The microcontroller was easy to program and handling with results broadly supportive systematic evaluation of the irrigation system.

Keywords: CUC; water-use efficiency; agricultural automation.

Avaliação automática de sistemas de irrigação por aspersão convencional

Resumo

Um dos problemas da irrigação é a alta demanda d'água, sendo que em certas ocasiões esta não está tão disponível, ou até mesmo em condições com disponibilidade ela deve ser preservada. Aliado a isso, a falta de acompanhamento e um manejo adequado do sistema vem proporcionando irrigações de baixa uniformidade e eficiência. Este trabalho visou desenvolver e testar um equipamento que seja capaz de avaliar o sistema de irrigação do produtor, tendo como parâmetros a lâmina média, e uniformidade de aplicação, de forma automática e simples. Testaram-se alguns sensores capazes de fazer leituras de nível d'água. Com o sensor definido foi construído o coletor de forma a levantar os dados para avaliação do sistema. Foram comparados os resultados obtidos com o sensor aos obtidos medindo o volume contido no coletor com auxílio da proveta graduada, sendo estes submetidos a testes estatísticos de comparação de médias. O dispositivo mostrou-se adequado para uso em condições de campo apresentando melhores resultados para lâminas maiores. O microcontrolador foi de fácil programação e manuseio, tendo resultados amplamente favoráveis a avaliação sistemática do sistema de irrigação.

Palavras-chave: CUC; água-uso eficiente; automação agrícola.

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Introduction

Among the many uses of water, its use in irrigation system becomes very important both for the irrigated area and for the volume required. One of the main problems of this issue is how it is used and, consequently, the waste with its misuse. Sousa *et al.* (2011) and Moraes *et al.* (2014), stress the importance of adopting measures that optimize the rational use of water, especially in irrigation, since this is increasingly scarce, and draws attention to the technological innovations that come to act as a partner in making agricultural processes. Moreira *et al.* (2012), demonstrates the need to monitor the amount of water applied to the crop as a way to enhance its use, especially when using the no-tillage system. This system generally applies a high irrigation depth, since the management is done based on the conventional planting system, without taking into consideration that in the direct tillage the water stays for longer time in the soil, which allows a smaller irrigation depth. One of the ways to monitor the amount of water applied as well as it is distributed throughout the area is due to the water application uniformity, since excessive irrigation depth can cause a low yield to the crop in addition to wasting water. Water application uniformity is an important way of monitoring the irrigation system, and low uniformities result in an irrigation depth applied besides the essential (Palaretti *et al.* 2011; Palaretti *et al.* 2016). Technology is an important ally of the water management process in irrigated agriculture. However, little has been studied specifically regarding the systemic and automated evaluation of irrigated areas. There is a real gap to be filled by the research groups in Brazil. The aim of this work was to develop and test an equipment capable of collecting the volume of water applied, treating it as an irrigation blade, and evaluating mainly the amount applied and the uniformity of the system. Since this equipment must do it automatically and systematically, allowing the irrigant its use throughout the crop cycle.

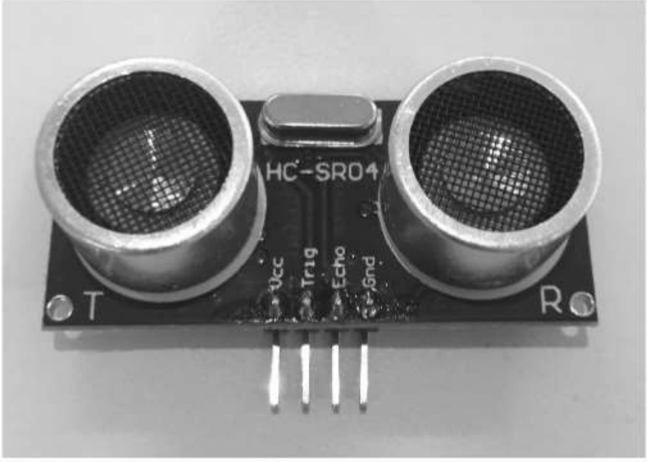
Methodology

This research was carried out at the Agricultural Sciences Institute (ICA) from Federal University of Minas Gerais (UFMG), Campus Montes Claros, Minas Gerais state, being part of the hydraulic laboratory and another in an experimental area.

The experiment was designed to simulate the irrigation assessment methodology proposed by Keller and Karmeli (1975) in an automated way, being the water collecting object and its calibration form developed for this purpose. The first part of the laboratory research was aimed at finding the most efficient and inexpensive means of measuring the water level within the catch cans and how to construct it. One of the assumptions followed was that the device should be at a lower cost and without major handling problems.

The catch cans were made of PVC pipes with a diameter of 75mm (44.178 cm^2 of collecting area) and 10cm in depth, being welded to the bottom in another piece of molded PVC in the shape of a blade. To avoid problems with upper edge water catchment area of the catch can the top edge was chamfered. Capacitive, resistive and ultrasonic level sensors were tested. The resistive level sensor, although presenting reasonable results, was discarded, because as the volume of water collected was generally small, there was a need for a more precise sensor. The capacitive sensor, although in other occasions, like the experiment of Araújo *et al.* (2007), presents satisfactory results, in this case presented a great problem of confection since the catch cans is of reduced size, resulting in a small capacitance, which compromised its use. Finally, the ultrasonic sensor was tested and approved. The ultrasonic sensor used was the HC-SR04, which reads from 2 to 4500 mm and has an accuracy of 3 mm (Figure 1).

Figure 1 – Sensor HC-SR04



To make readings with selected sensor was required a micro controlled module, opting for Arduino Mega model, which is easy to handle and presented necessary support as well as ports available for such task. The sensor should not obstruct the water inlet of the catch can. To solve this problem, it was coupled to the catch can another piece of PVC tube with 1 cm high unless than the catch can. This piece would communicate with the law of connected vessels, besides this would be closed so that the water did not enter through it (Figure 2).

After finalizing the device to obtain the water irrigation depth data, the laboratory tests were started. In this phase of the work an irrigation device was set up in which 25 catch cans with sensors were spaced 40 cm apart to collect the water applied by smalls sprinkler, allowing the calculation of the water uniformity application (Figure 3).

Figure 2 – Catch can with sensor.

Figure 3 – Test device in the laboratory with the catch cans

In this first test the sensor was programmed in a common way to the standard code found on the internet. However, the results were not as expected, so a specific recalibration was done for each catch can. Recalibration consisted of adding previously known water depths to all catch cans. With this, the sensor was calibrated for each blade added to the catch can. The irrigation depths corresponded to the volumes of 0, 50, 100, 150, 200, 250 and 300 mL, being made level readings of the sensor for each one. Each reading was repeated three times and averaged. Thus, a regression can be obtained and each sensor has a specific equation.

After this stage in the laboratory the experiment was started in an experimental area in which a conventional sprinkler irrigation system with 12 x 12 spacing was set up and again the 25 catch cans with sensors spaced 2 x 2 m were scattered, forming a mesh of catch cans (Figure 4).

Several irrigation depths were tested with irrigation time of 1; 1,2; 1.5; 2 and 2.5 hours of operation. Another fact to be observed is that these readings were made over 120 days, which is similar to a cycle of a culture equivalent to corn for example. In this way, as catch cans with sensors would be exposed to the sun and the weather of nature allowed to evaluate if these would not suffer some change with the time in use.

Figure 4 – Arrangement of catch cans for experimental area testing

Uniformity was calculated by the Christiansen's Uniformity Coefficient (CUC) by Equation 1,(Christiansen, 1942 citado por Mantovani *et al.*, 2007 and Paulino *et al.*, 2009):

$$\mathrm{CUC} = 100 * \left\{1 - \frac{\sum_{i=1}^{n}\left|x_i - x_{averg}\right|}{x_{averg} \cdot n}\right\} \text{ (Equation 1)}$$

where:

- Christiansen's Uniformity Coefficient, %

- the amount of water measured in each catch can while testing uniformity, mm

- average amount of water, mm

- the number of water accumulation catch cans

In order to analyze the results, the values of the average irrigation depths measured by the test tube and the sensor were compared. A statistical comparison of the means was performed, in this case the paired Tukey test (t test). There was also a comparison of the CUC values obtained by means of the sensor and measured manually.

Results and discussion

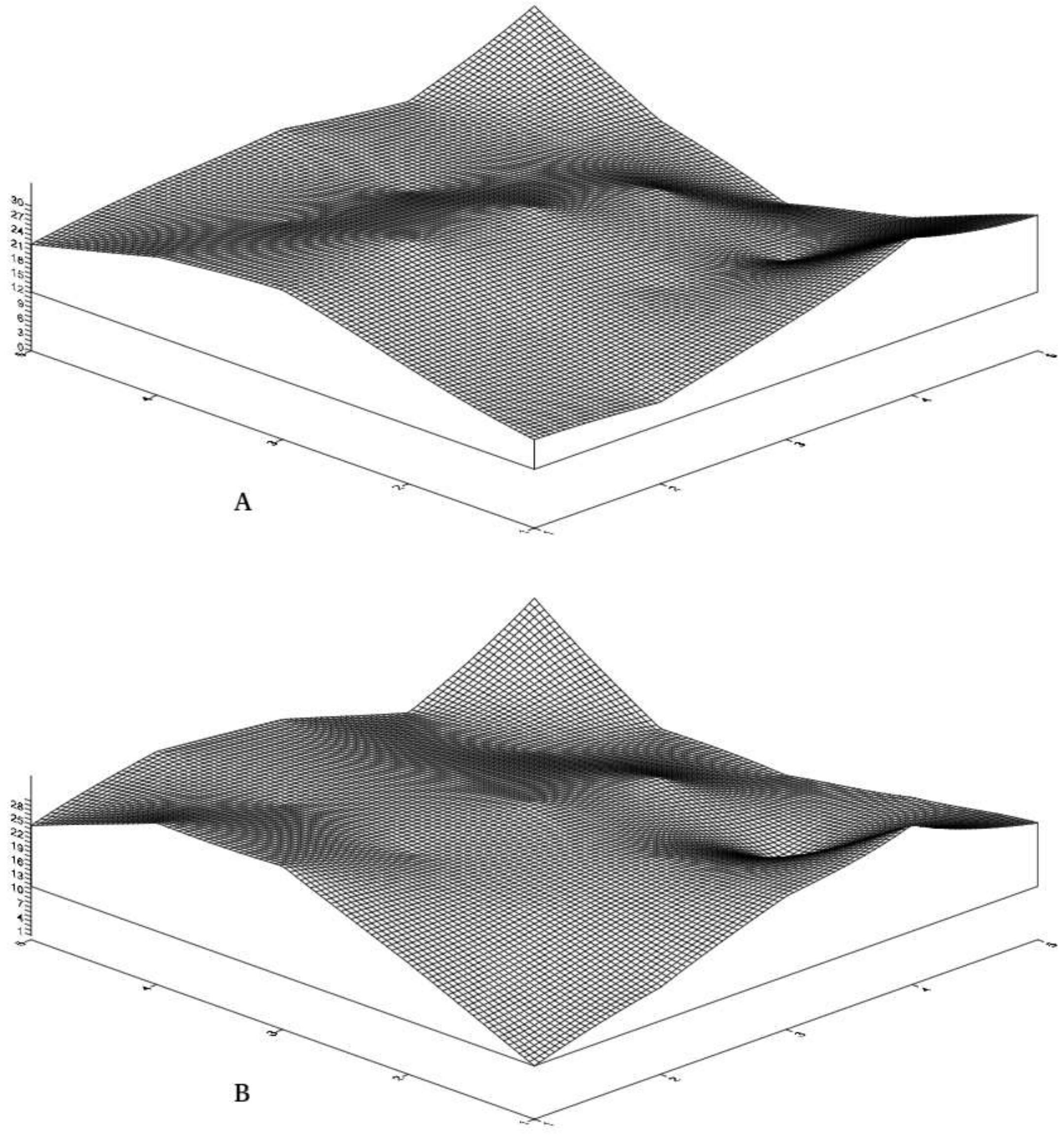
The first laboratory tests showed discrepancies between the CUC manually measured and the CUC measured by the sensor. This discrepancy was in the order of 20 percentage points lower when the sensor was used. This result can be related to the construction of the catch cans and mainly with the angulation of the sensor inside the catch can.

Despite the discrepancy, it was noticed that the sensor did not present variations in the values obtained for the same irrigation depth in the same catch can. Therefore, to reduce the discrepancy between sensors, the individual calibration was performed for each catch can. As a result of the calibration, a linear regression was obtained, resulting in the equation:

$Y = 5.22412x + 1.4481$ with $R^2 = 0.9978$.

With the calibrated sensors, a new test was performed in a laboratory in which good results were obtained. The average value of irrigation depth and CUC was 25.5 mm and 83% for the water manually measured and 25.5 mm and 80% measured by the sensor, respectively. Figure 5A and Figure 5B represented the distribution profile of water.

Figure 5 – Distribution profile of water. (A) manually measured, (B) measured by the sensor.

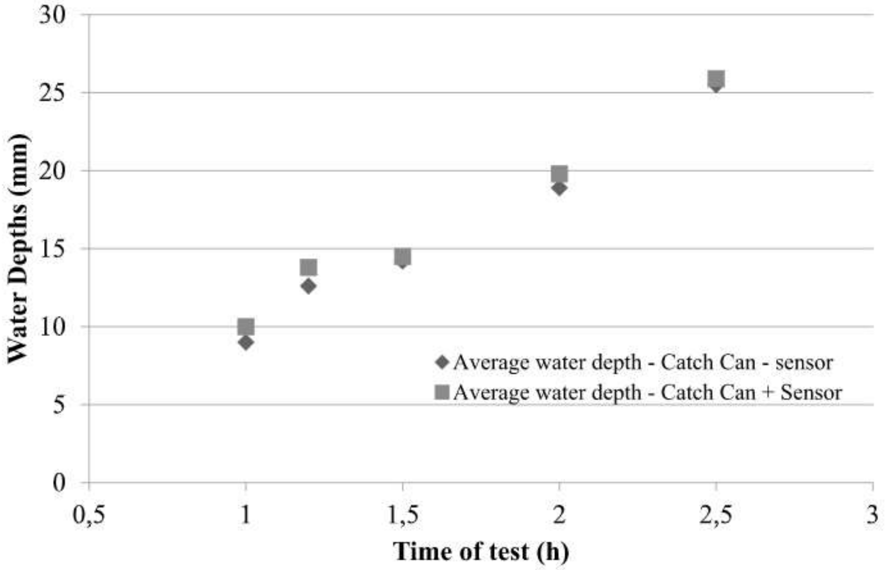


CUC values were considered to be very good for manually produced catch cans. The graphs show the similar behavior of CUC for both types of catch cans. Thus, the catch can with the sensor to evaluate the water uniformity application was approved in the field test (Graphic 1).

When the paired t-test was performed for each of the water depths pairs (catch cans with and without sensor), it was concluded that all were equal to a significance level of 5%. Except for the second test which showed the greatest difference between the means of water depth.

The values of α for the paired t-test were 0.0703; 0.0268; 0.682; 0.2599; 0.6549, respectively to the irrigation times of 1; 1.2; 1.5; 2 and 2.5 hours of irrigation operation. These values when greater than 0.05 show equal means, i.e., the level of significance was considered at 5%.

Graphic 1 – Average water depths in different irrigation times

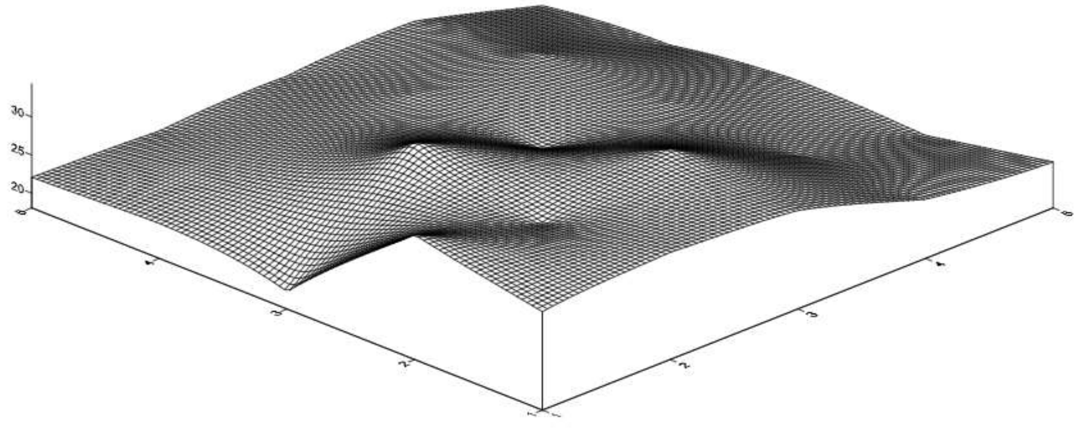


The higher this value, the more reliable the possibility of being equal. Among the values of α, those of irrigation time equal to 1 and 1.2 h presented a lower reliability in the equipment. These values can be explained by the fact that in the shortest time the volume collected is smaller, which gave the sensor a certain level of imprecision. Such a problem can be solved by constructing a larger catchment area collector, i.e. collectors with cone element formats to provide greater storage height, resulting in a higher reading level of the sensor, which would make it more accurate. For the remaining irrigation times, the comparison between the means was very reliable.

This fact can be explained because the catch cans in the field did not have the same leveling conditions of the laboratory, besides the fact that in the field there are more variables and external factors such as wind drift, as cited by Faria *et al.* (2012) and Faria *et al.* (2016).

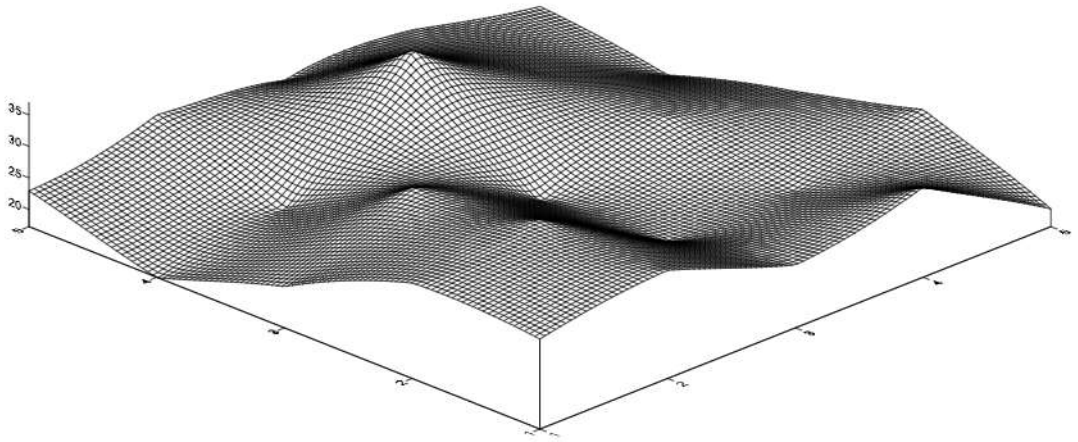
As the average water depth relates all values directly, it can present an average close to the expected, but with great variation of the individual values. On the other hand, the CUC correlates the deviation of each observation, therefore, it is possible to have two close averages, but with different uniformities, this fact may have happened with the values obtained with the aid of the sensor. Even with reasonably different values, mainly in CUC, the experiment was evaluated positively, mainly because the difference in average was of 6.2% for CUC and 0.86 mm for average water depth. Another important fact to evaluate is the distribution of the water depth, i.e., where the water depth was bigger or smaller. This result can be seen in Figure 6 and 7.

Figure 6 – Distribution of water depth using catch can without sensor



In relation to the distribution of the water depth, the two figures have a certain similarity, where the maximum and minimum locations appear in the same points, having in some places the smaller values mainly in Figure 8, but nothing that compromises the use of the device.

Figure 7 – Distribution of water depth using catch can with sensor.



Another point observed in the experiment was the resistance of the device to climatic weather, and the device always performed reliable readings throughout the experiment. The only problem occurred in the seal that prevented water from entering the tube that contained the sensor and should be improved.

Conclusion

- The sensor was effective in measuring the water level and its resolution of 3 mm presented no problems to the experiment;
- The sensor was resistant to weathering, being suitable for use under field conditions;
- The microcontroller was easy to program and handle, with results widely favorable to the systematic evaluation of the irrigation system;
- The developed equipment presented satisfactory results allowing the automatic and systematic evaluation of an irrigated area.

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