The importance of metrology and measurements in the application of drip irrigation in horticulture

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Abstract. The paper describes advantages of drip irrigation in horticulture. The importance of metrology and measurements in the drip irrigation system was explained. The effect of "gross errors" in the measurement results on the system was explained, and the method of further increasing the accuracy by processing the results obtained from measuring instruments and not taking into account "gross errors" was justified by concrete examples and diagrams. The disadvantage of using the conventional method has been pointed out. Using the proposed method, the maintenance of soil moisture in a stable state during the processing of the results obtained from the sensors was considered. This method allows saving a certain amount of water and more accurately measure soil moisture.

1 Introduction

Nowadays, as water resources in the world are decreasing, there is a need to use water-saving technologies in all areas. The WRI's Aqueduct tools show that 17 countries in which a quarter of world population lives is "extremely high" water stress, where irrigated agriculture, industries and municipalities eliminate more than 80% of their affordable proposals on average every year. Forty-four countries, home to a third of the world's population, face "high" levels of stress, with more than 40% of available stocks being withdrawn on average every year. According to the study, Uzbekistan is placed in the category of "high basic stress of water", which, along with the republic, includes countries such as Kyrgyzstan, Belgium, Spain, Portugal, Armenia, Turkey, Italy and others.

Thus, the Republic of Uzbekistan is considered one of the countries with a high-water deficit [1]. For example, the situation in 164 countries was studied by the World Resources Institute (WRI), and in a report published on August 6, 2019, Uzbekistan ranked 25th in terms of water scarcity [2].

Water scarcity can be eliminated through proper management. Even countries with relatively high levels of water scarcity can overcome this scarcity through proper management. An example of this is the "Qatrah" ("drop" in Arabic) program launched by Saudi Arabia, which ranks 8th in terms of water scarcity. In addition, Namibia, ranked 37th, has been converting wastewater into drinking water for the past 50 years.

Another article on the World Resources Institute website lists the following 3 main ways to reduce water scarcity:

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1. Increasing the efficient use of water in agriculture;
2. Investment in gray and green infrastructure;
3. Clean, reuse and recycle.

Focusing on the first of these ways, efficient use of every drop of water in growing food is extremely important. For this, it is advisable for farmers to use seeds that require less water or to use water-saving irrigation systems instead of over-watering their land.

Drip irrigation has been introduced and is being used in many countries. The drip irrigation method is distinguished by its high efficiency, that is, it allows obtaining a stable high yield with low water consumption in conditions of limited water resources [3, 4].

2 Materials and methods

The drip irrigation system is being improved every year and enriched with modern technologies.

However, any modern technology gives the expected efficiency only when it works correctly. That is, the basic information on which this technology relies must be reliable. In other words, the data obtained from the measuring instruments used in the system should be of high accuracy, that is, it should be free of errors as much as possible. Because the control panels in the system make decisions based on the data obtained from this measurement tool, and give commands to the execution mechanisms based on this data. Even small, seemingly insignificant errors in the data obtained from measuring instruments turn into significant errors by the time they reach the final stage. This error may not cause damage to the system or ground, but, as we mentioned above, the expected maximum level of efficiency cannot be achieved.

So, what to do about it? Is it necessary to use high-precision measuring tools? But what about using them correctly? After all, without solving this problem, it would be unreasonable to talk about high accuracy.

Then let's consider the issue of how to use measuring tools correctly and obtain more accurate measurement data through them.

Soil moisture is the main parameter in the drip irrigation system. The water pump operates in one of the "speed mode", "medium mode" and "sleep mode" modes according to the average value of the results obtained continuously from humidity sensors in the area it is responsible for. After the soil moisture reaches the required value, the mode is changed, i.e., if it is working in the "fast operation" mode, it will switch to the "medium mode", while it is working in the "medium mode" it will switch to the "sleep mode".

The dependence of the operation mode of the water pump on the value of soil moisture is presented in Table 1.

Table 1. Dependence of the pump operation mode on the value of soil moisture.

Average moisture of the soil $\bar{\sigma}$, %	Operating mode of the pump
$\bar{\sigma} \leq 55$	speed mode
$55 < \bar{\sigma} < 70$	medium mode
$\bar{\sigma} \geq 70$	sleep mode

It is the question of obtaining this average value that is very important. Because the value of moisture in some places may differ sharply from the value of moisture in another place, or some sensors may incorrectly measure the value of soil moisture. Such results are considered a "gross error" in the theory of measurements. Although such a difference does not affect the final value very much, as we mentioned above, the expected maximum efficiency cannot be achieved.

So, how can you determine if this is the case and how to reduce the impact on the final result?

All currently available systems take the average value in almost the same way [5, 6]:

$$\overline{\sigma} = \frac{\sum_{i=1}^{n} \sigma_i}{n} \tag{1}$$

where n the number of moisture sensors installed in the area, σ_i the humidity value received from the i-th sensor (%).

We will consider this method with concrete examples.

20 sensors are installed in the area as shown in Figure 1 [7].

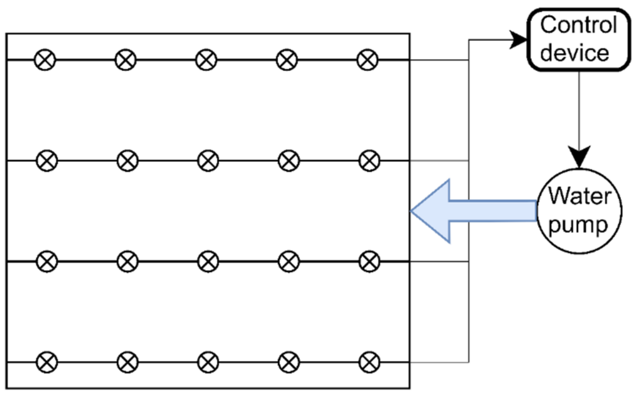

Fig. 1. Installation of moisture sensors in the area.

The results obtained from 20 sensors installed in the area in a certain time interval are presented in Table 2:

Table 2. Changes in moisture over time.

Time, *hh:mm*	***i***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**		$\overline{\sigma}$
09:00	σ_i, %	30	31	30	29	29	30	***24***	30	29	30		
09:30		40	39	41	40	40	41	40	40	***30***	41		
10:00		50	51	49	50	***58***	51	50	49	49	50		
10:30		59	58	***52***	59	61	60	60	***51***	59	60		
11:00		65	68	65	64	***69***	65	***69***	63	64	65		
11:30		71	70	71	71	70	71	70	69	***61***	69		
Time, *hh:mm*	***i***	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**		
09:00	σ_i, %	***23***	***37***	30	31	29	30	***38***	30	31	30		**30.05**
09:30		40	41	39	41	40	40	39	40	40	***31***		**39.15**
10:00		51	50	***57***	49	49	51	50	***59***	49	50		**51.1**
10:30		61	59	61	59	***53***	59	60	61	59	61		**58.60**
11:00		65	64	64	65	64	64	***69***	64	65	65		**65.30**
11:30		71	70	70	69	68	***62***	72	71	70	69		**69.25**

The average moisture values calculated using formula (1) are presented in the last column of Table 1. Everything seems to be in order. However, each time a humidity value is transmitted, the humidity values from several sensors differ more than others. These results introduce an error into the final value calculation. As proof of this, we can say that the last time the result was obtained, that is, at 11:30, the humidity in almost all places reached 70%, but since the average result was 69%, until 12:00 the pump works in "medium mode" . As a result, soil moisture exceeds the norm.

In order not to take such "gross errors" into account when calculating the average result, we use the following method [8]:

Step 1: The percentage difference of each result from the arithmetic mean value is calculated using formula 2.

$$\beta_i = \frac{\sigma_i}{\overline{\sigma}} \qquad (2)$$

Step 2: Values that differ by more than 5% from the arithmetic mean are not taken into account when performing formula 1.

3 Results

Table 3 shows how many percentages each result differs from the average arithmetic value.

Table 3. Deviation of the results from the average value.

Time, *hh:mm*	***i***	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
09:00	β_i, %	-0.2	3.2	-0.2	-3.5	-3.5	-0.2	***-20***	-0.2	-3.5	-0.2
09:30		2.2	-0.4	4.7	2.2	2.2	4.7	2.2	2.2	***-23***	4.7
10:00		-2.2	-0.2	-4.1	-2.2	***13.5***	-0.2	-2.2	-4.1	-4.1	-2.2
10:30		0.7	-1.0	***-11***	0.7	4.1	2.4	2.4	***-13***	0.7	2.4
11:00		-0.5	4.1	-0.5	-2.0	***5.7***	-0.5	***5.7***	-3.5	-2.0	-0.5
11:30		2.5	1.1	2.5	2.5	1.1	2.5	1.1	-0.4	***-12***	-0.4

Time, *hh:mm*	***i***	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
09:00	β_i, %	***-24***	***23***	-0.2	3.2	-3.5	-0.2	***26***	-0.2	3.2	-0.2
09:30		2.2	4.7	-0.4	4.7	2.2	2.2	-0.4	2.2	2.2	***-21***
10:00		-0.2	-2.2	***11.5***	-4.1	-4.1	-0.2	-2.2	***15.5***	-4.1	-2.2
10:30		4.1	0.7	4.1	0.7	***-10***	0.7	2.4	4.1	0.7	4.1
11:00		-0.5	-2.0	-2.0	-0.5	-2.0	-2.0	***5.7***	-2.0	-0.5	-0.5
11:30		2.5	1.1	1.1	-0.4	-1.8	***-10***	4.0	2.5	1.1	-0.4

According to Table 3, the highlighted values exceed the corresponding average value by more than 5%. Therefore, we can consider them as "gross errors" [9-11].

If these values are not taken into account, we find the average values again using formula 1. These values are listed in Table 4.

Table 4. Average values without taking "gross errors" into account.

Time, *hh:mm*	$\bar{\sigma}$	$\bar{\sigma}_2$
09:00	**30.1**	**29.9**
09:30	**39.2**	**40.1**
10:00	**51.1**	**49.9**
10:30	**58.6**	**59.8**
11:00	**65.3**	**64.6**
11:30	**69.2**	**70.1**

The average values with and without the "gross errors" are different from each other. We can see this difference in Figure 2.

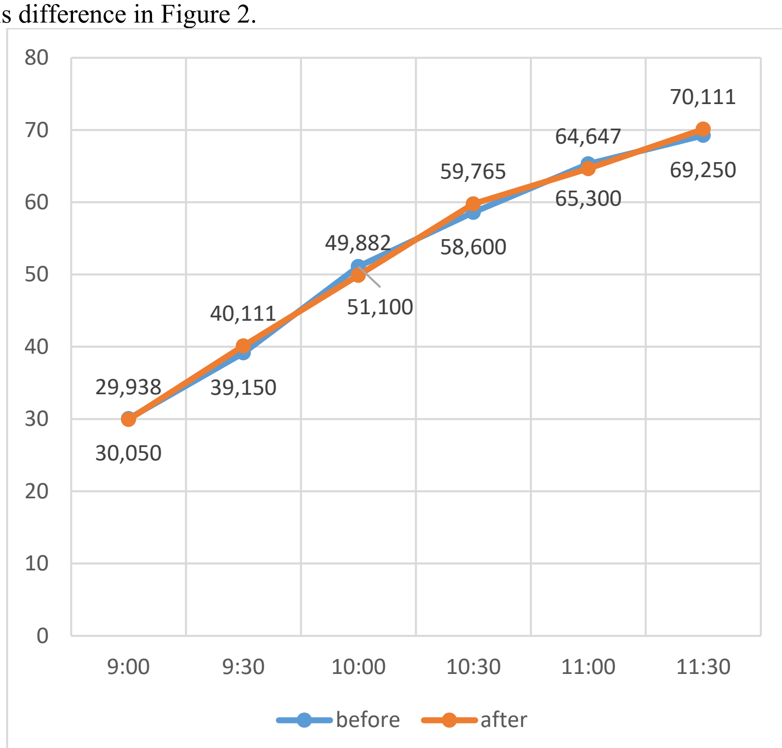

Fig. 2. The difference between the average values.

Looking at Figure 1, we can conclude that not taking into account the "gross errors" during decision-making can affect the result even if it is small.

In addition, the second proposed issue is changing the frequency of water pump pressure depending on the weather. In addition to the above method, this also allows to further increase productivity. That is, the pressure of the water pump is different at different temperatures and humidity of the air. This method can be understood from Figure 3

 https://doi.org/10.1051/e3sconf/202339004027

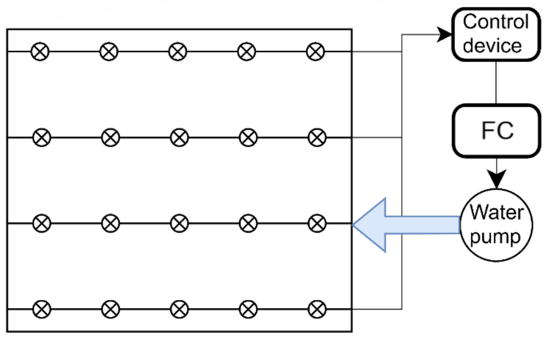

Fig. 3. The scheme of connecting the frequency converter to the drip irrigation system.

The frequency converter installed after the control device helps to save water even more. This frequency converter is manually adjusted by the operator through the manual.

4 Conclusion

We have considered the issue of obtaining the average value from humidity sensors installed in the drip irrigation system. In this case, sharply different results from some sensors can significantly affect the average value, and as a result of this effect, the wrong command goes to the pump. We saw the proof of this in the humidity value at 11:30. If a "gross error" is involved in the calculation of the results, the humidity can go up to about 75% by the time of the next measurement, and the quality will certainly be affected, albeit slightly. It is through this example that the importance of measurement theory and metrology can be seen in this system.

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