The prospects of using precision irrigation

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Abstract. The purpose of the presented work was to develop technical means for precision irrigation of agricultural crops, to assess the prospects of the technology. The article discusses the possibilities of upgrading a wide-reach sprinkler machine. A variant with block control of sprinklers according to the accelerated scheme and direct control of the sprinkler through an individual solenoid valve was studied. The characteristics of the machines are considered. In particular, the change in the precipitation layer depending on the irrigation regime. An assessment of the Christiansen irrigation efficiency coefficient is given for various irrigation regimes. Conclusions are drawn about the effectiveness and expediency of using precision irrigation technology.

1 Introduction

Precision farming is an innovative method aimed at optimizing resource management for the sustainable development of agriculture.

The characteristics of rain supply should vary depending on spatial differences in the soil, such as structure, topography, ability to retain moisture, as well as the level of infiltration and drainage. Therefore, the need for irrigation may vary in different areas of the same field. Excessive or insufficient amounts of water significantly affect yields, product quality, and economic performance.

The inability of traditional agriculture to account for changes in these factors within the field not only has a negative economic impact due to reduced yields, but also negatively affects the ecological state of the environment due to the excessive use of agrochemicals, fertilizers and water.

Thus, the need for irrigation may vary in different zones of a particular field and should vary depending on the spatial variability of the soil.

The works of many scientists are devoted to differentiated irrigation systems and technologies [1-13].

The aim is to develop technical means and devices for wide-range sprinklers for precision irrigation of agricultural crops, ensuring that the volume of water corresponds to the required level of moisture reserves of field areas at the time of their irrigation, and evaluating the prospects of using the technology.

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2 Materials and methods

Currently, the following methods of implementing precision irrigation can be distinguished:
- Control of individual sprinklers or units with multiple sprinklers;
- Changing the speed of the sprinkler and dividing it into irrigation sectors;
- Dynamic flow control throughout the pipeline.

The control of individual sprinklers or units with several sprinklers can be carried out by turning them on or off, i.e. by the ratio of watering time and pause or by changing the flow section of the nozzle of the sprinklers. The choice of method depends on the specific irrigation conditions, in particular the variability of soil properties and conditions.

In any case, it is necessary to divide the field into small areas, and then develop individual management of each site using agricultural resources (fertilizers, herbicides, water), taking into account the specifics of the site.

The amount of water supplied to the soil during each watering depends on how much time has passed since the last watering and how much water the crop has used since then.

The first option requires maximum modernization of the sprinkler machine. The adjustable water supply is carried out using programmable logic control and electromagnetic valves. The scheme of modernization of the sprinkler machine is shown in Figure 1.

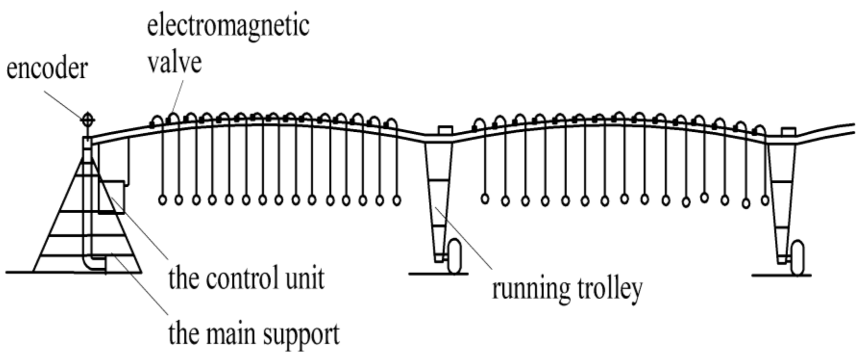

Fig. 1. The scheme of modernization of the sprinkler machine

To implement precision irrigation, two main tasks need to be solved. Defining site boundaries and managing precise irrigation.

The encoder converts the angular position of the machine into a digital code.

To evaluate the effectiveness of precision irrigation, two design solutions were studied.

In the first variant, the control was carried out individually by each sprinkler of a single-span machine through an electromagnetic valve. Electromagnetic valves were installed at the beginning of each vertical pipe (gander), which is connected to the drain irrigation pipes. Drain irrigation pipes are installed through 2.2 m, Figure 2.

Fig. 2. CASCADE Sprinkler Machine

The second option was mounted on one of the spans and included a block control system for sprinklers with their rapid installation after 0.5 m and an additional horizontal polymer pipe. An electromagnetic valve controlled the sprinkler unit.

The determination of irrigation control zones was based on measurements of soil electrical conductivity using sensors. The study used the Seed'OS_5 soil moisture assessment system [3].

The readings were taken on a grid at a distance of 4-6 m from each other.

Field studies were conducted on light chestnut medium loamy soils with the lowest moisture capacity of 20 crops - alfalfa. The wind speed is less than 1.5 m/s. Circular irrigation sprinkler –CASCADE, Figure 3.

Fig. 3. CASCADE sprinkler machine (installation)

The amount of water supplied was regulated by the on-off time of the valve (pulsation) and the setting of the machine movement timer. In start-stop mode, it is also measured by the ratio of driving time and parking time (PV%).

3 Results

Irrigation zones were identified on the field using sensor-based measurements. Based on measurements of soil moisture within each zone, it is possible to determine the lack of soil moisture and the required amount of water.

Based on the gradation, six zones of available water content were allocated.

The analysis shows that their distribution is not uniform. The first and fifth zones are the smallest, 2 and 3%, respectively. In total, they account for 0.33 hectares, Figure 4. The largest are the second and third zones, with a total area of 6 hectares. The average value of the available water content is 135 mm.

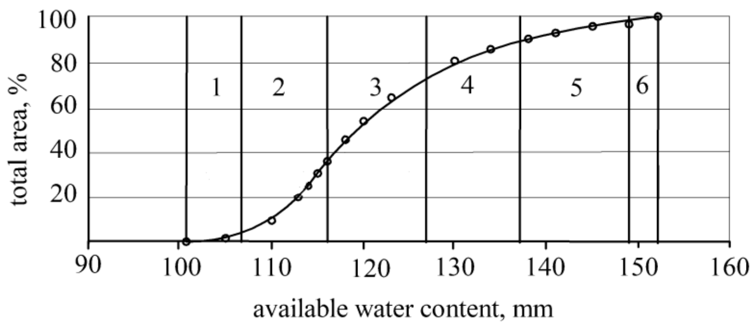

Fig. 4. Zoning of the area according to the content of available water

Comparing the characteristics with the standard irrigation technology with a single norm, it can be concluded that the proposed irrigation technology in this irrigation area will not significantly save resources, but will ensure environmentally safe irrigation, which is especially important when considering irrigation in the future.

In the second version of the modernization, the precipitation layer issued by the machine under different modes was determined by rain gauges. A comparison of the required precipitation layer and the one produced at different machine speeds is shown in Table 1.

Table 1. Precipitation layer at different machine speeds

Ripple, %	The speed of the machine is 20%		The speed of the machine is 40%	
	Measured precipitation layer, mm	Theoretical precipitation layer, mm	Measured precipitation layer, mm	Theoretical precipitation layer, mm
10	2,6	2,16	1,2	1,00
30	5,5	6,33	2,5	3,02
40	7,6	8,51	3,4	4,12
60	12,1	12,61	5,6	6,11
70	14,2	15,17	6,2	7,24
90	19,3	19,23	8,2	9,27
100	21,0	21,30	10,1	10,13

Since the valves have some inertia of operation, it was necessary to assess the effect. The research results did not reveal a significant impact in either the first or the second version of modernization.

Nevertheless, the measurements showed some deviations at the boundary of the control zones, as well as fluctuations in the irrigation radii with sprinklers.

A much greater problem was the selection of sprinklers with a stable irrigation radius and high uniformity, since the overlap of a layer of precipitation from neighboring sprinklers affects the accuracy of water delivery as a whole.

The machines used the author's deflector type sprinklers, Figure 5.

Fig. 5. Author's sprinklers

The radius of spraying water with a sprinkler should not exceed the distance between the sprinklers.

The research results showed that the use of the presented method of water supply did not have a negative effect on the uniformity of water supply compared with the uniformity of water supply by a traditional irrigation system, Table 2.

Table 2. Coefficient of uniformity for different irrigation modes (second upgrade option)

Valve pulsation level, %	**Christiansen irrigation efficiency coefficient**	
	at a speed of 20%	at a speed of 40%
10	76	75
30	89/*87	92/*89
40	91	89
60	95/*90	90/*88
70	94	92
90	96	97
100	98	96

* values for the first upgrade option

The advantages of the developed system are increased crop yields, economical use of resources through the use of variable flow rates, optimization or saving of water and electricity.

4 Conclusions

To determine the effectiveness of precision irrigation, it is necessary:

-Digitize the estimated irrigation area. Determine the characteristics of the soil.

-Develop a map of the total available water content.

-To zone the irrigation area with a generalization of nearby zones.

With a difference of more than 20%, the use of precision irrigation is economically justified.

-To estimate the area of plots of different zones of available water content. In the presence of two or more zones with an area of more than 10% each, the use of precision irrigation is economically and environmentally justified.

Precision irrigation reduces resource costs. The effectiveness depends on the ratio of the component parameters of the variability of the experimental site or field. Fields that are characterized by spatial variability benefit from the use of a precision irrigation system.

There is no doubt about the environmental expediency of using precision irrigation technology, which allows avoiding negative environmental impacts, improving product quality and saving resources.

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