Applying the Precision Irrigation Technology to Address the Deficit of Water Resources in the South of Russia

Sergey M. Vasilyev, Alexander N. Babichev, and Vladimir I. Olgarenko

Abstract The development of precision irrigation is caused by the need to account for soil, climate, water, organizational, and economic specifics of the fields and plots. Precision irrigation reduces the consumption of water, energy, and other resources. It increases the effectiveness of tending to crops, raises the productivity of plants, and maintains even soil moisture on all plots. In 2019, we conducted a two-factor field test on the territory of the "Biryuchekut Olericulture Experimental Station"—a branch of the "Federal Research Centre of Vegetable Production." In the test, we planted spring potatoes. As a result, we established the following technical characteristics: crop yield, total water consumption, irrigation norm, and water balance coefficients. We established the dependency of spring potato yield on the total dose of fertilizers and water consumption in precision irrigation. We analyzed the field experiment results and concluded that precision mineral fertilization and precision irrigation are the most effective methods of growing spring potatoes.

Keywords Precision irrigation · Mineral fertilizers · South of Russia · Natural moisture deficit · Technology · Spring potatoes

1 Introduction

The development of new technologies and software increased the efficiency of conventional farming methods and presupposed the appearance of new ones. One of the new farming methods is precision irrigation. Precision irrigation allows receiving stable and high yields, conserving limited water resources, and following sustainable development principles [1].

Precision irrigation is mainly implemented by constant monitoring of nutrients and moisture in soils of micro-plots [2]. Currently, agricultural operations do not account for the small-scale changes and variability of soils. Therefore, the yields of

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specific crops fluctuate significantly. This method also leads to increased resource consumption, soil degradation, and reduced efficiency of irrigated agriculture [3, 4].

Precision agriculture controls the water distribution per unit of land, thus leveling the soil moisture content and reducing the anthropogenic stress on limited water resources. Conserving water is a top priority in Russia and the entire world [5].

Smart sprinklers are currently being developed in Russia and abroad. They allow monitoring water consumption on each segment of the irrigated area, thus leveling soil moisture and decreasing loss of productive moisture. This allows improving the productivity and efficiency of crops while conserving water [6, 7].

Plot-specific application (i.e., considering all specific features of crops and soils) of nutrients, fertilizers, pesticides, and other agrochemicals is more economically efficient. It increases the productivity of crops and reduces impractical resource use. This technology is the most conducive to precision irrigation. It allows saving resources, increasing agricultural production profitability, and maintaining soil fertility [8].

2 Materials and Methods

We propose developing an information management system. This system is based on remote sensing data and governs plant growing, irrigation, and other activities. The model of the information management system and its functional structure is presented below (Fig. 1).

In this study, we conducted a field experiment on experimental field plots. The experiment was repeated three times [9].

The main objective of the experiment is to establish the impact of precision irrigation and mineral fertilizers on the productivity of spring potatoes. The experiment is two-factor.

Factor 1 "Irrigation method":

(1) No irrigation (control group);
(2) Dosage recommended by the zonal cropping systems [ZCS] [10];
(3) Precision irrigation.

Factor 2 "Mineral nutrition":

(1) No fertilizers (control group);
(2) Dosage recommended by the ZCS;
(3) Precision dosage.

The experiment was conducted on the territory of the "Biryuchekut Olericulture Experimental Station" (Yasny village, Bagaevsky district of the Rostov Region). The predominant type of soil is ordinary chernozem with medium humus content. The boiling line (from the increased content of hydrochloric acid) is at a depth of 40–50 cm; the clay content in the 0–1.0 m soil layer is more than 55%.

The experiment site is in the center of the irrigated agriculture zone of the Rostov region. The climate is hot and arid. The Hydro-thermal Coefficient of Selyaninov

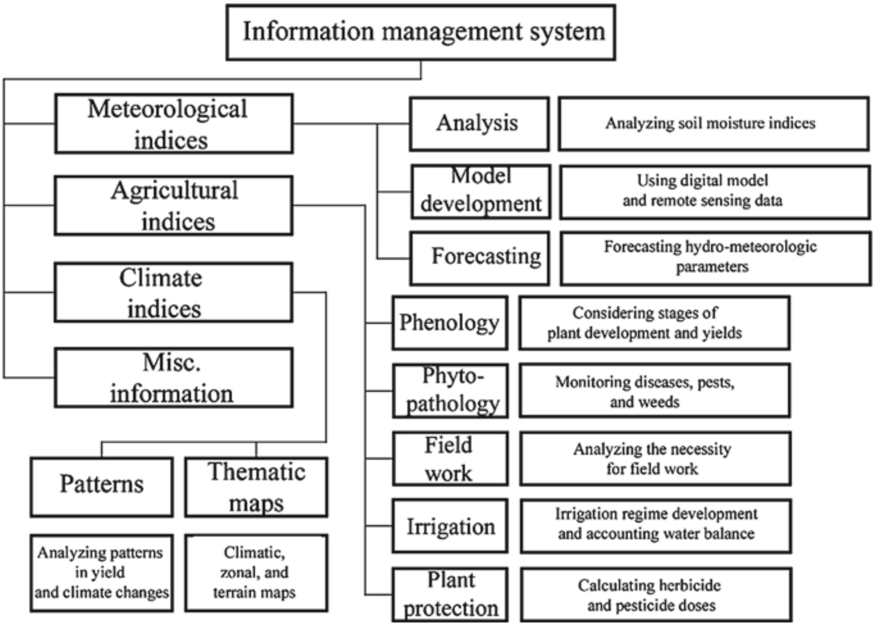

Fig. 1 Functional structure of the information management system

(HTC) is less than 0.7; the Territorial Moisture Coefficient of N. N. Ivanov (TMC) is 0.33–0.44. The sum of positive temperatures in the growing season is 3200–3400 °C. The temperatures reach the mark of 10 °C in mid-April. The annual precipitation is 500 mm, only around 250 mm in the growing season. In the experiment, precise irrigation was implemented by using hyperspectral imaging data (remote sensing).

3 Results and Discussion

The experiment allowed us to establish the influence of various cultivation technologies on the yield, productivity, sum water consumption, irrigation norms, and water consumption coefficient of spring potatoes. The results are presented in Tables 1 and 2.

The productivity of spring potatoes changed significantly:

- From 12.2 to 22.1 t/ha in non-irrigated plots;
- From 25.2 to 43.7 t/ha in plots irrigated according to ZCS recommendations;
- From 28.1 to 45.2 t/ha in plots with precise irrigation.

The fertilizer-caused increases in productivity were 9.9, 18.5, and 17.1 t/ha (more by 0.7, 2.3, and 3.5 t/ha, respectively, compared to ZCS recommendations). The irrigation-caused increases in productivity on the plots with precision fertilizer

Table 1 The productivity of spring potatoes depending on the irrigation technologies and fertilizer dosage

	Productivity, t/ha	Increase			
		From irrigation		From fertilizers	
		t/ha	%	t/ha	%
No irrigation					
No fertilizers	12.2	–	–	–	–
N_{160} P_{180} K_{160} (recommended by ZCS)	21.4	–	–	9.2	75.4
$N_{160}P_{175}K_{150}$ (precision dosage)	22.1	–	–	9.9	81.1
80% lowest soil moisture in 0.6 m horizon (recommended by ZCS)					
No fertilizers	25.2	13.0	106.6	–	–
N_{160} P_{180} K_{160} (recommended by ZCS)	41.4	20.0	93.4	16.2	64.3
$N_{160}P_{175}K_{150}$ (precision dosage)	43.7	21.6	97.7	18.5	73.4
Precision irrigation					
No fertilizers	28.1	15.9	130.3	–	–
N_{160} P_{180} K_{160} (recommended by ZCS)	41.7	20.3	94.9	13.6	48.4
$N_{160}P_{175}K_{150}$ (precision dosage)	45.2	23.1	104.5	17.1	60.9
HCP_{05}	2.43				

dosage were 20 and 21.6 t/ha (more by 1.6 and 2.8 t/ha, respectively, compared to ZCS recommendations).

By analyzing the experiment data, we established the empirical dependency of productivity dynamics on fertilizer application. We compared two dynamic curves: with ZCS-recommended irrigation and with precise irrigation (Fig. 2). The curve equations (quadratic equations with corresponding approximation coefficients) are presented in Formulas 1 and 2:

$$Y = -0.43 \cdot \sum NPK^2 + 7.26 \cdot \sum NPK + 14.11,\ R^2 = 0.85 \tag{1}$$

$$Y = -0.29 \cdot \sum NPK^2 + 5.63 \cdot \sum NPK + 19.6,\ R^2 = 0.88 \tag{2}$$

where

Y Is productivity, t/ha,
$\sum NPK$ Is sum fertilizer dosage, kg/ha.

Depending on fertilizer dosage, the water consumption of spring potatoes changed in non-irrigated plots from 2996 to 3343 m^3/ha; in plots irrigated according to ZCS recommendations from 4365 to 4562 m^3/ha; and in precision-irrigated-plots from

Table 2 Water consumption depending on fertilizer application and irrigation method

	Sum water consumption, mm	Irrigation norm, m^3/ha	Water balance deficit coefficient, m^3/t	Water consumption coefficient, m^3/t
No irrigation				
No fertilizers	296.6	–	–	243.1
N_{160} P_{180} K_{160} (recommended by ZCS)	334.3	–	–	156.2
$N_{160}P_{175}K_{150}$ (precision dosage)	320.7	–	–	145.1
80% lowest soil moisture in 0.4 m horizon (recommended by ZCS)				
No fertilizers	436.5	2.100	83.3	173.2
N_{160} P_{180} K_{160} (recommended by ZCS)	462.4	2.100	50.7	111.7
$N_{160}P_{175}K_{150}$ (precision dosage)	456.2	2.100	48.1	104.4
Precision irrigation				
No fertilizers	444.5	2.012	71.6	158.2
N_{160} P_{180} K_{160} (recommended by ZCS)	459.5	2.012	48.2	110.2
$N_{160}P_{175}K_{150}$ (precision dosage)	452.5	2.012	44.5	100.1

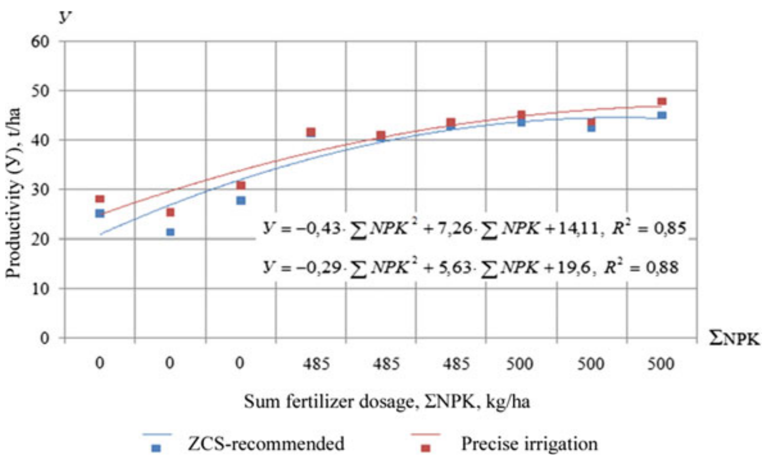

Fig. 2 Dynamics of productivity, depending on the sum fertilizer dose with ZCS-recommended and precise irrigation

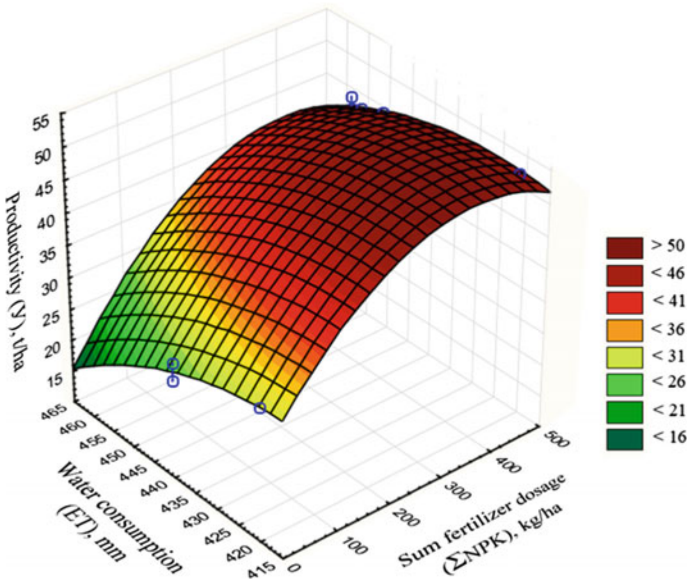

Fig. 3 The dependency of potato productivity on fertilizer application and water consumption in precision irrigation

4445 to 4525 m^3/ha. The irrigation norm was 2100 m^3/ha in ZCS-recommended irrigation, and 2012 m^3/ha in precise irrigation.

The empirical dependency of potato productivity on fertilizer application and water consumption in precision irrigation is presented in Fig. 3. The equation of the dependency is presented in Formula 3:

$$Y = -885.15 - 0.04 \cdot \sum NPK + 4.46 \cdot ET - 1 \cdot 10^{-4} \cdot \left(\sum NPK\right)^2 + 4 \cdot 10^{-4} \cdot ET \cdot \sum NPK - 0.05 \cdot ET^2 \quad (3)$$

where

Y	Is productivity, t/ha,
$\sum NPK$	Is sum fertilizer dosage, kg/ha.
ET	Is water consumption, mm.

4 Conclusion

We concluded that the precision application of fertilizer is highly effective, both in terms of productivity (45.2 t/ha) and water balance coefficients (44.5 and 101.1 m^3/ha). The indexes of water balance and potato productivity can be to calculate and forecast the use of natural resources in the irrigated floodplain of the Lower Don. Precision irrigation can only be implemented by using the modern systems of crop and field monitoring. These technologies provide data on soil moisture and soil nutrient content. Precision irrigation allows leveling the soil moisture and nutrient content in all plots, providing higher crop productivity, and conserving natural resources.

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