BIO Web of Conferences **66**, 03003 (2023) https://doi.org/10.1051/bioconf/20236603003
AgriScience2023

Technological solutions are environmentally friendly safe watering with wide-ranging sprinkler machines

Larisa Zhuravleva*

Russian State Agrarian University - Moscow Timiryazev Agricultural Academy, 127434, Timiryazevskaya street, 47, Moscow, Russia

Abstract. Erosion processes in the Russian Federation remain one of the main sources of loss of soil and crop fertility resources, deterioration of land conditions. The implementation of an environmentally safe irrigation process with wide-coverage sprinklers is an urgent problem and requires improvement of technology, technological techniques for soils with low water permeability. The aim of the study was to optimize the operating mode and technological methods of irrigation with wide-reach sprinklers, adaptation to conditions changing during the irrigation period, exclusion of over-watering and water erosion of soils. The article discusses the schemes of differentiated distribution of irrigation norms and the movement of wide-reach sprinkler machines of circular and frontal action, ensuring compliance of the irrigation norm with the level of moisture reserves of field areas at the time of their watering, reducing the environmental burden on the soil and preserving fertility.

1 Introduction

In the natural and climatic conditions of most regions of the Russian Federation, stable development of agricultural production is possible only with additional irrigation to natural humidity.

Currently, the total area of irrigated land in Russia is 4.28 million hectares, of which 1.8 million hectares are watered. The main irrigation technique is wide-reach sprinkler machines. Currently, there are about 13.5 thousand units [1, 2].

Irrigation by sprinkling is a provoking factor in the development of erosion processes and soil degradation. Erosion processes in the Russian Federation remain one of the main sources of loss of soil fertility resources and, accordingly, crop yield. As a result of erosion, the condition of the most fertile soils in Russia – chernozems - is deteriorating. Their area is 120 million hectares, which is 7% of the total land fund. Nevertheless, almost 60% of all arable land is located on this area and about 80% of crop production is produced [3].

The damage caused by erosion consists not only in the erosion of the soil, the transfer of eroded material, but also in the significant loss of soil nutrients, especially calcium and phosphates, i.e. elements that predetermine soil fertility [4-8].

* Corresponding author: dfz@yandex.ru

It has been established that on slightly washed soils, the crop shortage can be 10-20%, on medium–washed soils – 40-60%, and on strongly washed soils - 80% or more. It should be noted that different crops are not equally sensitive to soil washout [3].

Thus, the yield of leguminous crops on washed soils decreases by about 10%, corn – up to 60%, and sugar beet – up to 80% [3].

The implementation of an environmentally safe, soil-sparing, resource-saving high-quality technological process of irrigation with wide-reach sprinklers requires a new thoughtful approach and solutions.

The purpose of the study is to optimize the operating mode, schemes and technological methods of irrigation with wide–reach sprinklers to adapt to conditions changing during the irrigation period, to exclude over-watering and water erosion of soils.

2 Research methodology

For wide-reach sprinkler machines of circular action. Let's consider the case of a machine working with a reverse, when there is no return of the machine to the starting point after passing a full circle. I.e., the machine returns to the point φ, moving in the opposite direction reversely. In this case, watering with the same norm at the beginning of the return causes runoff and a simplified adjustment is required.

Since structurally the irrigation rate does not change continuously when moving, we divide the total irrigation area into sectors, at the specified points of which the speed of the machine will change and, consequently, the irrigation rate.

The optimal value of the norm for watering, depending on the total number of sectors and the sector number, is determined from the expression [9, 11-13]:

$$M_i' = 2\pi \frac{1200 Q_M}{\ell V(\varphi)} \left[1 - \frac{1}{(1+10E\xi\ell)^{n+1-i}}\right], \quad (1)$$

i – plot number from the reference point or parking position of the car, $i=1,2\ldots n$; n – total number of partitioning sections; Q_M – machine consumption, l/s; V – average speed of the car; ℓ – arc length of the sector, m; E – total water consumption equal to the intensity of water consumption, mm;

$$\xi = \frac{s}{432 \cdot 10^3 К \, Q_M}, \quad (2)$$

$К$ – time factor; s – the path traversed by the last cart.

To ensure the uniformity and quality of irrigation before the operation of the sprinkler machine, a irrigation map should be drawn up, where irrigation standards are assigned by sector, determined from the expression (1).

When passing the specified points of the sector, information from a GLONASS/GPS beacon and a weather station installed near the irrigation site via a GLONASS satellite to a GLONASS receiver and then to an intelligent module, a command is given to start watering the irrigated sector at a given machine speed.

The use of the proposed technology also ensures the uniformity and quality of irrigation when the machine is working with reverse and not passing a full circle, including when watering areas of a specific shape or obstacles installed on irrigation areas.

For wide-reach sprinklers of frontal action.

Irrigation rate $M_1 (x)$ at the point of the beginning of the field when the machine moves from point x = 0 (first pass), m^3/ ha [10]:

$$M_1(x) = \frac{600 Q_M}{B V(x)}, \quad (3)$$

B - the width of the machine, m; V - the average speed of the car, m / h.

Change of moisture reserves in the soil in front of the machine in a straight course [10]:

$$f_1(x) = W_H - 10E\xi \int_0^x M_1\,(x)dx. \quad (4)$$

W_H - initial moisture reserves, m^3/ha.

After the passage of the machine at time t, the moisture reserves will be determined:

$$W_1 = f_1\,(x) + M'_1\,(x), \quad (5)$$

$$M'_1(\mathrm{x}) = \frac{600Q_M}{\mathrm{B}V(\mathrm{x})}\left[1 - \mathrm{e}^{10\mathrm{E}\xi(\mathrm{x}-\ell)}\right], \quad (6)$$

If, when moving in the opposite direction in front of the machine, the moisture reserves in the soil are represented by the function $f_2(x)$, then behind it they are determined from the expression:

$$W_2 = f_2\,(x) + M'_2\,(x). \quad (7)$$

ℓ - the length of the irrigation area, m.

$$M'_2(\mathrm{x}) = \frac{600Q_M}{\mathrm{B}V(\mathrm{x})}\mathrm{e}^{10\mathrm{E}\xi(\mathrm{x}-\ell)}. \quad (8)$$

Depending on the total number of the plot and the number of the plot, the irrigation rate on the i-th plot M_i is determined by:

$$M'_{\mathrm{i}} = \frac{600\mathrm{Q_M}}{\mathrm{BV(x)}}\left[1 - \frac{1}{\left(1+10\mathrm{E}\xi\frac{\ell}{\mathrm{n}}\right)^{\mathrm{n}+1-\mathrm{i}}}\right], \quad (9)$$

i - plot number from the beginning of the field, *i=1,2…n; n* - the total number of partitioning sections.

3 Research results

For circular sprinklers. Conditions: the specified irrigation rate is 300 m3/ha. The length of the machine is 300 m. The time utilization factor is 0.8. The consumption of the machine is 41L/s. Optimization of the irrigation rate when divided into 4 sectors and 6 sectors, according to expression (1) is shown in Fig.

Thus, by setting the path that the last cart passes, it is possible to determine the optimal value of the norm when watering in one direction and in the opposite direction.

In the absence of technical possibilities for obtaining information about the state of the soil and weather station data , optimal irrigation technologies for soils with low water permeability can be reduced to three schemes:

- watering with a given rate in one turn;
- watering with a given norm for two turns with equal norms;
- in the first turn, the norm is set equal to 2/3 of the specified.

If the erosion-permissible irrigation rate is more than 300 m^3 /ha, the specified norms up to 400 m / ha can be introduced according to 1 option; norms 500-600 m^3 /ha - according to the second, and if the erosion-permissible irrigation rate is less than 250-300 m^3 /ha, then 400 m^3 /ha will need to be used option 2, and with large data norms - the third.

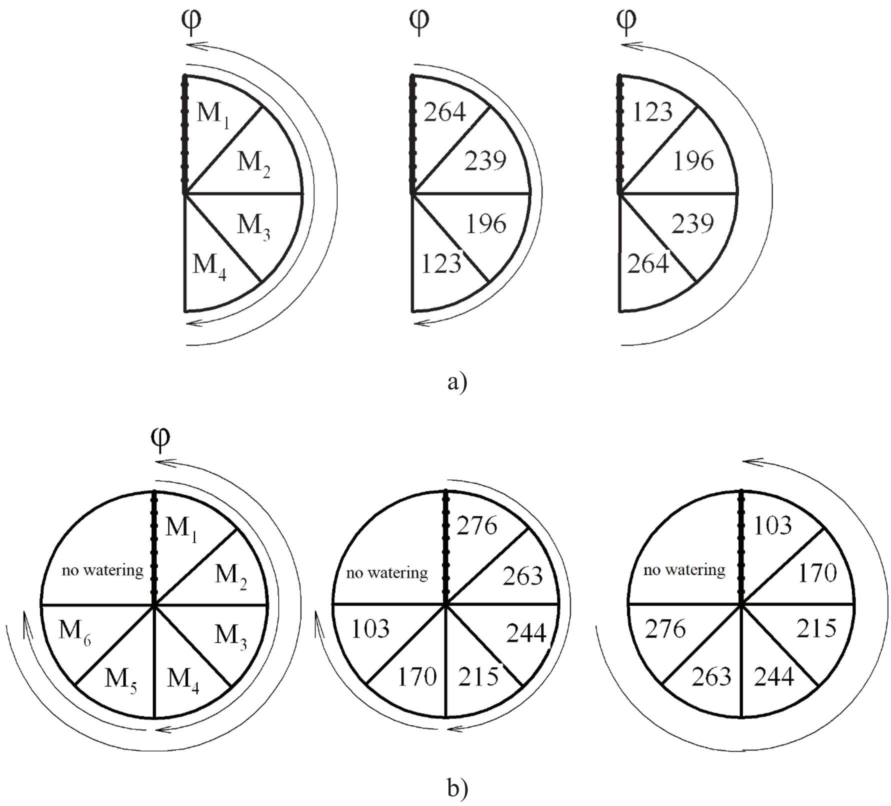

Fig. 1. The scheme of dividing the irrigation circle info sections-sectors: a) – optimization of the irrigation rate when divided into 4 sectors; b) – into 6 sectors

Considering the movement of the frontal action machine, it is also possible to distinguish the following irrigation schemes with frontal DM, Fig. 2

Issuance of irrigation norms for the passage:

- issuance of irrigation norms for two passes by half norms;
- issuance of irrigation norms in two passes with switching of the operating mode in the middle of the field;
- issuance of irrigation norms with switching the driving mode to 1/3 and 2/3 of the field length.

4 Conclusion

One of the main criteria when choosing sprinkler equipment, its characteristics and irrigation technology should be the preservation of soil fertility, reduction of surface runoff and non-productive losses of irrigation water.

Existing irrigation technologies with wide-reach sprinkler machines have a disadvantage due to the fact that watering with a constant rate does not always correspond to the value of the required moisture, depending on different moisture availability in different sectors or sections of the irrigated field, which leads to overspending of irrigation water, increased runoff and soil erosion.

Recommended irrigation rates for schemes 3 and 4 at high rates can be issued in accordance with Table 1.

The conducted research allowed us to recommend technological irrigation techniques taking into account the peculiarities of soil and climatic zones, in particular on soils of medium and low water permeability, adapted to conditions changing during the irrigation period.

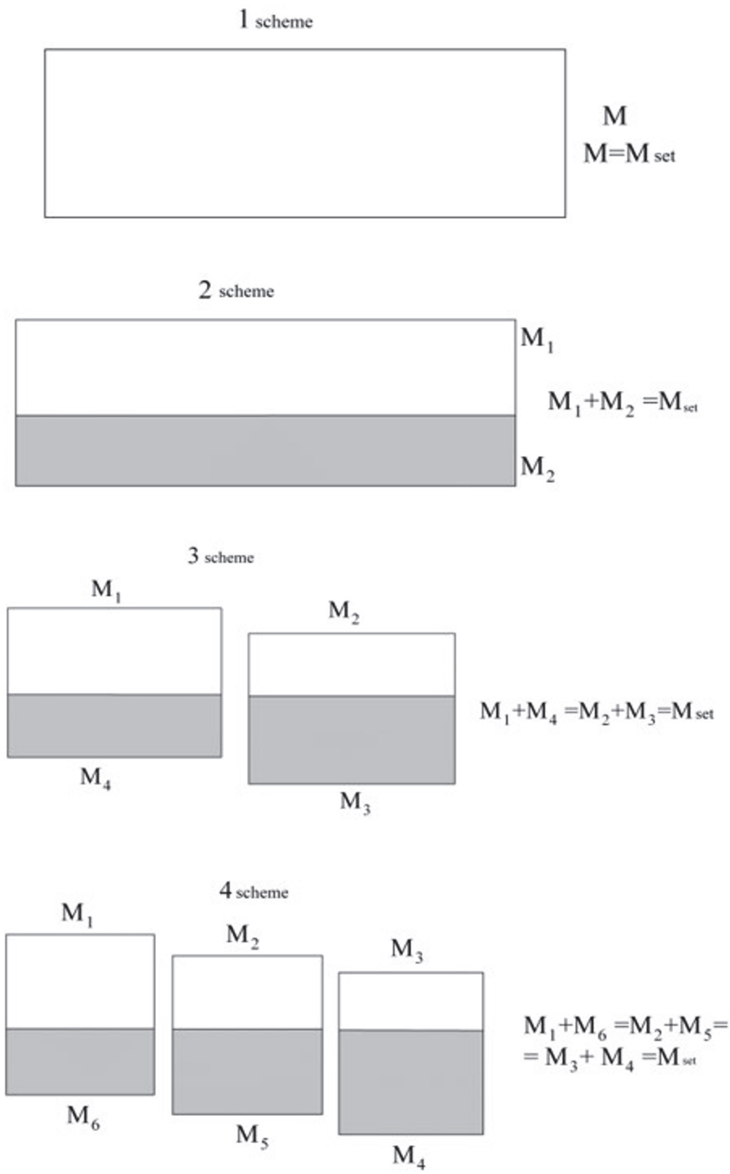

Fig. 2. Irrigation schemes with front sprinklers

Table 1. Irrigation standards for schemes 3 and 4 with high irrigation rates

Scheme number	The specified norm, m^3/ha	The norm on the plots	Area, ha			
			до 160		более 160	
			June, September	July, august	June, September	July, august
3	400	M_1	250	280	260	300
		M_2	150	180	170	200
		M_3	250	220	230	200
		M_4	150	120	140	100
3	500	M_1	240	280	280	310
		M_2	140	190	170	210
		M_3	360	310	330	290
		M_4	260	220	220	190
3	600	M_1	290	360	330	400
		M_2	170	220	200	250
		M_3	430	380	400	350
		M_4	210	240	270	200
4	500	M_1	250	310	290	350
		M_2	180	240	310	280
		M_3	100	140	120	160
		M_4	400	350	380	340
		M_5	320	260	290	220
		M_6	250	190	210	150
4	600	M_1	300	390	340	420
		M_2	220	290	260	330
		M_3	120	170	150	200
		M_4	480	430	450	400
		M_5	380	310	340	270
		M_6	300	210	250	180

Acknowledgements

The article was made with support of the Ministry of Science and Higher Education of the Russian Federation in accordance with agreement № 075-15-2022-317 date April 20, 2022 on providing a grant in the form of subsidies from the Federal budget of Russian Federation. The grant was provided for state support for the creation and development of a World-class Scientific Center "Agrotechnologies for the Future".

References

1. A.V. Medvedev, *Meliorative technology – the basis of sustainable agricultural production*, Mater. Inter. scientific-practical. internet conf (2016)
2. V.V. Melikhov, *Melioration – potential and development strategy of agro-industrial complex and rural territories of Russia* (2016)
3. *Ways to improve the efficiency of irrigated agriculture: collection of scientific tr. FSBI RosNIIPM*, **50** (Novocherkassk, Helikon, 2013)
4. J. S. Aarstad, D. E. Miller, Soil Sci. Soc. Am. J., **45(1)** (1981)
5. M. J. Brown, J. Soil and Water Conservation, **40(4)** (1985)
6. D. L. Carter, C. E. Brockway, K. K. Tanji, J. Irrig. and Drain. Engrg., ASCE, **119(6)** (1993)

7. C. Dadio, W. W. Wallender, Trans. ASAE, **28(2)** (1985)
8. T. Trout, W.H. Neibling, *Erosion and Sedimentation Processes on Irrigated Fields*, Journal of Irrigation and Drainage Engineering-asce (1993)
9. A.I. Yesin, L.A. Zhuravleva, V.A. Soloviev, *Resource-saving technologies and circular sprinkler machines monograph*, (Saratov, FGOU VPO Saratov GAU, 2019)
10. B. P. Fokin*, Improving the efficiency of irrigation with multi-support rain machines*: dis. ...doctor of technical sciences (Stavropol, 2002)
11. L. A. Zhuravleva, AIP Conf. Proc. **2767**, 020010-1–020010-9 (2022)
12. A. A. Skvortsov, L.A. Zhuravleva, *Theoretical Foundations of Water-Conducting Belt Design for Wide Coverage Sprinklers Using Numerical Simulation*, IOP Conf. Series: Materials Science and Engineering 994 (2020).
13. L.A. Zhuravleva, I. A. Popkov, *Improving the patency of sprinkler machines on moistened soil on the basis of experimental and theoretical studies of the system irrigation rate-soil-sprinkler machine*, IOP Conference Series Earth and Environmental Science **949(1)** (2022)