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Theoretical study of the influence of the changing environment on the process of rainfall irrigation

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Abstract. The technology of sprinkler irrigation has a higher coefficient of land use compared to that of regular irrigation, due to the absence of irrigation erosion, the prevention of unnecessary absorption of water into the soil, the high degree of mechanization and automation of the irrigation process, the saving of equipment and fuel costs, the availability of irrigation in areas with uneven relief, the uniform moistening of the root layer. It has the advantage of achieving the same growth and development of the plant in all parts of the field. At the same time, there are opportunities to achieve savings as a result of giving mineral fertilizers in the form of suspension during irrigation. This article examines the distribution of water droplets on the field surface during sprinkler irrigation and the influence of wind speed on the intensity of irrigation. Water drop motion and wind motion were analyzed in one coordinate system. As a result, a mathematical model of the resistance coefficient of the environment and the movement of a water droplet in a variable environment was developed. Keywords: Drip irrigation, water droplet, changing environment, distance of droplet flight.

1 Introduction

In the Republic of Uzbekistan, great attention is being paid to the development of measures aimed at eliminating the negative consequences of the increasing demand for water resources and the wide implementation of water-saving irrigation technologies, including the use of rain irrigation technology in the irrigation of agricultural crops [1-4].

Due to the fact that the state support mechanisms are being adapted to the requirements of the times in Uzbekistan on the basis of these privileges and opportunities [5], water-saving technologies were introduced in 433 thousand hectares in 2021, and their total figure is 17% of the irrigated areas [6], and the areas irrigated based on drip irrigation technologies are 290,300 [7-10]. Sprinkler irrigation 13,500, discrete irrigation technology 10,600, flexible pipe irrigation 299,700, film-laying irrigation technology 92,000, and land leveling with the help of laser equipment was carried out to 185,800 hectares. Irrigation of agricultural crops through the sprinkler irrigation system is understood as artificial rain over the crop and soil

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by turning water into small water droplets with the help of special sprinkler devices [11-15]. The sprinkler irrigation method is an engineering irrigation method designed to deliver the appropriate amount of water to the plant's needs using sprinklers directly to its root layer [16-20]. Currently, the use of sprinkler irrigation system is considered one of the most common irrigation methods in the world irrigation practice and is being introduced in the irrigated fields of countries such as Spain, Israel, India, Turkey, USA, China, Saudi Arabia, Ukraine, and Russia [21-25].

The technology of sprinkler irrigation has a higher coefficient of land use compared to that of regular irrigation, due to the absence of irrigation erosion, the prevention of unnecessary absorption of water into the soil, the high degree of mechanization and automation of the irrigation process, the saving of equipment and fuel costs, the availability of irrigation in areas with uneven relief, the uniform moistening of the root layer [26]. It has the advantage of achieving the same growth and development of the plant in all parts of the field. At the same time, there are opportunities to achieve savings as a result of giving mineral fertilizers in the form of suspension during irrigation. A drop of water is blown away by the wind during sprinkler irrigation. The flying of a drop of water under the influence of the wind was studied in the researches of M.I. Nazarov, I. Shtangey, V.V. Slyusarenko, G.P. Nadezhkina, and it was determined that the greater the height of the water drop above the earth's surface, the greater the water wastage [27-33]. According to SANIIRI (Uzbekistan), when the rate of irrigation with the Fregat sprinkler is 614 m^3/ha, water loss due to evaporation reaches 30%. When the wind speed is 3 m/s, the droplet removal is 7-10%, and evaporation is 13.7-20.7% when the ambient temperature is 25-30 °C, when the wind speed increases from 1.1 to 3.1 m/s is enough [34, 35]. All studies uniformly emphasize that as the flight time and flight height of the water drop increases, the wind blowing and evaporation of the water drop increases [36-40].

In the conducted scientific and practical studies, the effect of wind on the flight of a water droplet was considered in a separate coordinate system [2]. This reduces the accuracy of the obtained results.

2 Materials and Methods

Taking into account the dependence of the hydrodynamic parameters of the water flow on the structural dimensions of the nozzle, using the mathematical model of the trajectory of the water drop during the raining process, it is possible to determine the dependence of the flight distance and trajectory of the water drop on the wind speed [3-6].

The mathematical model of the movement of a water drop has the following form [3,4]:

$$x(t_{i+1}) = x(t_i) + \vartheta_x(t_i)\Delta t; \tag{1}$$

$$y(t_{i+1}) = y(t_i) + \vartheta_y(t_i)\Delta t\,. \tag{2}$$

Let's consider the movement of a drop of water and wind in one coordinate system. In a variable environment, let the water droplet have the speed ϑ, and the wind the speed ϑ_w. In that case, the equation representing the resistance of the environment under the influence of the wind will have the following form:

$$\vec{F}_{RE\ T}(t) = \frac{C_x\,\rho_m\ S}{2}\,\vartheta^2 = \frac{C_x\,\rho_m\ S}{2}\left(\sqrt{{\vartheta_x}^2\,(t) + {\vartheta_y}^2(t)} - \vartheta_w \sin\theta\right), \tag{3}$$

Where, ϑ_w is wind speed, m/s; θ -the angle between the water flow and the wind direction, grad.

Taking into account the effect of wind, the variable coefficient of the environment in formulas (4) and (5) can be written in the following form [3]:

$$K_1(t) = -\left(\frac{18\mu}{\rho_c d^2} + \frac{\rho_m C_x\left(\sqrt{\vartheta_x{}^2(t)+\vartheta_y{}^2(t)}-\vartheta_w \sin\theta\right)}{4\rho_c d}\right), \quad (4)$$

The initial speed of a water droplet is expressed as follows:

$$\vartheta_x(0) = |\vec{\vartheta}(o)|\cos\alpha - \vartheta_w \sin\theta \ ; \quad (5)$$

$$\vartheta_y(0) = |\vec{\vartheta}(o)|\sin\alpha \, . \quad (6)$$

Then equations (1) and (2) will look like this:

$$x(t_{i+1}) = (1 + K_1(t_i)\Delta t)\vartheta_x(t_i); \quad (7)$$

$$y(t_{i+1}) = \left(\frac{p_c}{p_t} - 1\right) \cdot 9{,}81 \cdot \Delta t + (1 + \ K_1(t_i) \cdot \Delta t \cdot \vartheta_y(t_i). \quad (8)$$

The initial velocity of the water droplet is taken as the velocity of the droplet at the orifice of the nozzle tube. The velocity losses of the water flow in the deflector were determined by the following formula [8]:

$$\vartheta_2 = \sqrt{\vartheta_0^2 - \ 2g(h_2 - h_1) - \gamma \frac{L \ \vartheta_0^2}{D})} \ , \quad (9)$$

Where, $\gamma -$ coefficient of hydrodynamic loss; ϑ_0 - velocity of the water droplet in the hydrosystem of the nozzle; h_1, $h_2 -$ height of the water drop in the nozzle deflector, in our case $h_1 = 0$; L - hydrosystem length; D - nozzle diameter.

3 Results and Discussion

The distribution of water droplets on the field surface and the effect of wind speed on the flight distance are presented in the graphs in Figures 1 and 2. The diameter of the graphic water droplet is 2 mm, the installation height of the nozzle is 0.5 m, the flight angle of the water droplet is 30o, the angle between the wind and the axis perpendicular to the water direction is 30o, the tube diameter is 8 mm against the direction of the water flow at different values of the wind speed (Figure 1) and taken in the water direction (Figure 2).

At the wind speed ϑ_w = 0 m/s, the water drop is uniformly distributed on the surface of the field in the form of an ellipse. As the wind speed increases, a sharp shift of the distribution along the wind direction can be observed. The calculations showed that the flight time of the water drop also changes.

The distribution graph of the water flow on the field surface (Figs. 1c, 2c) was obtained by projecting the distance of the water drop flying from the deflector segments onto the XZ axes.

The change in the flight distance of a water drop depends on the value of $\vartheta_i(t)$ - the sum of the flight speed of the drop and ϑ_w - wind speed, as well as the value of the variable

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coefficient of the environment $K(t)$. It can be seen that the flight distance and flight time of the water droplet increase when the wind direction is in the direction of the water flow.

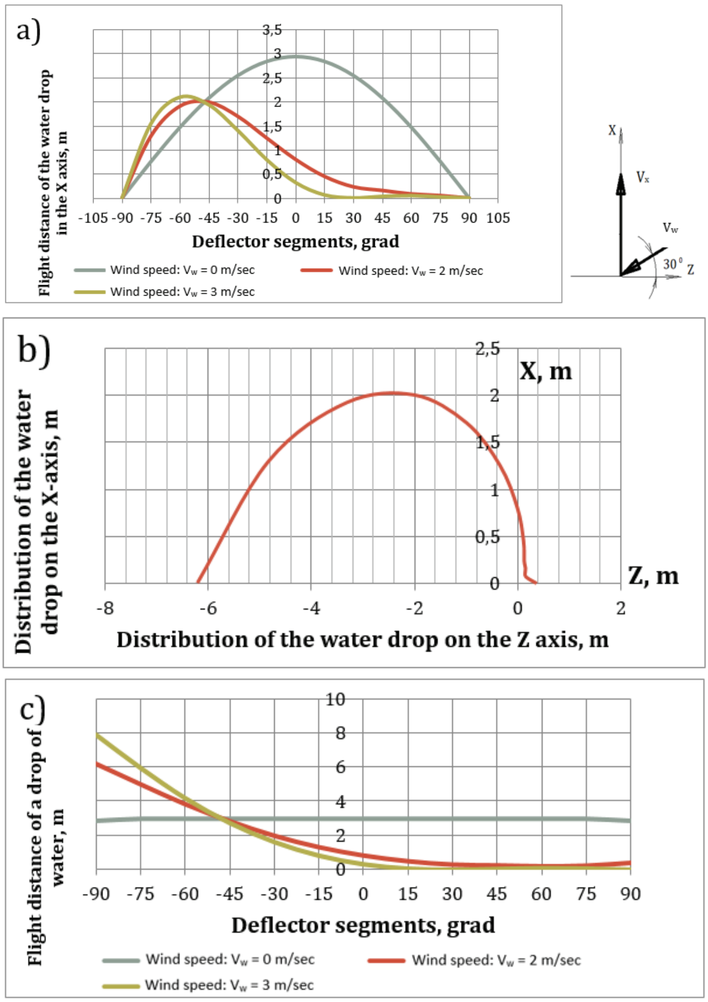

Fig. 1. The effect of wind speed on the distribution of water droplets on the field surface and flight distance when the wind speed is directed against the water flow: a) The effect of wind speed on the distribution of water flow on the field surface; b) Water flow distribution diagram on the field surface, c) Flight distance of a drop of water under the influence of wind.

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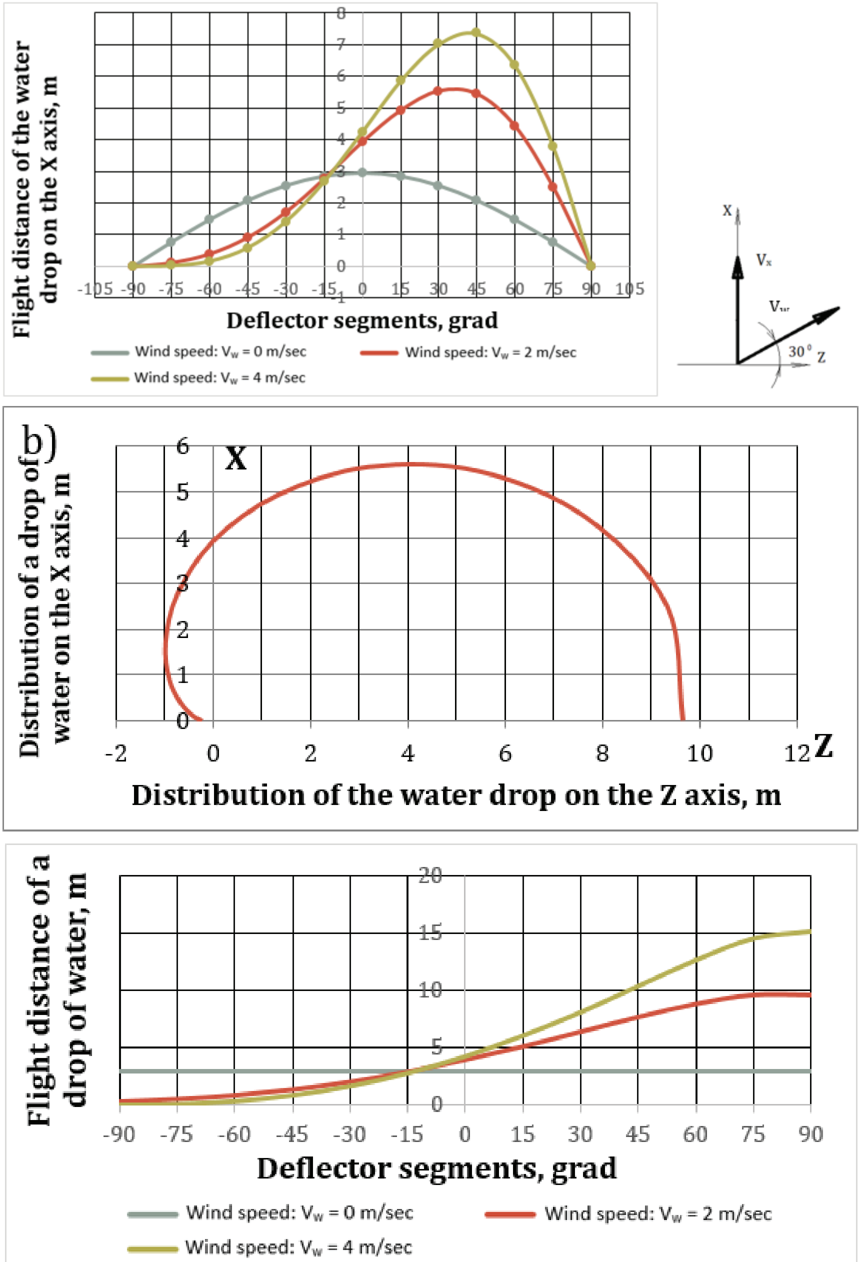

Fig. 2. The effect of wind speed on the distribution of water droplets on the field surface and flight distance when the wind speed is directed along the water flow: a) The effect of wind speed on the distribution of water flow on the field surface; b) Water flow distribution diagram on the field surface; c) Flight distance of a drop of water under the influence of wind.

It can be seen from the graph that at ϑ_w = 0 m/s (Fig. 1a), the flight distance of the water droplet is L = 2.94 m. When the wind speed is equal to ϑ_w = 2-3 m/s, the flight distance decreases and is L = 1.93-1.99 m. It should be noted that the largest values of the water droplet velocity belong to the water droplet ejected from the segments located at 45-60 degrees and move to the 2nd half of the deflector. Deformation of the velocities of raindrops from the segments in the 1st half of the deflector under the influence of wind speed is observed.

The graph in Figure 1 b shows the distribution of water flow on the field surface as a result of the deformed velocity. It can be seen from the graph that the water flow distribution shifts along the Z axis and $|-6{,}2; 0{,}2|$ located in the section.

The change in the flight distance of a water drop under the influence of wind is depicted in the graph in Fig. 1 c. When the wind speed varies in the range of ϑ_w = 2-3 m/s, the flight distance of the water droplet in the 1st half of the deflector has a critical small value. It reaches its maximum value in the 2nd half of the deflector. When the wind speed ϑ_w = 3 m/s reaches L = 8 m.

The graphs in Figure 2 show the position of the water droplet readings when the wind speed is in the direction of the water flow.

4 Conclusions

The mathematical model of water drop movement obtained as a result of theoretical research includes the structural and technological parameters of sprinkler devices. With the help of a mathematical model, it is possible to model the technological mode in various parameters. Through this, it is possible to optimize both structural and technological parameters of sprinklers.

References

1. N.F. Ryzhko, *Substantiation of resource-saving sprinkling and improvement of the Fregat sprinkling machine in the conditions of the Saratov Trans-Volga region. Abstract of Doctor of Technical Sciences. according to special 06.01.02 Reclamation, reclamation and land protection* (Saratov, 2012)
2. N. Namozov, B. Teshaboev, M. Saidova, D. Kodirova, M. Usmanova, M. Tursinbaev, IOP Conference Series: Earth and Environmental Science **1068(1)**, 012033 (2022)
3. Z. Khudayorov, R. Khalilov, I. Gorlova, S. Mirzakhodjaev, A. Mambetsheripova, E3S Web of Conferences **365**, 04011 (2022) https://doi.org/10.1051/e3sconf/202336504011
4. Z.J. Khudoyorov, Sh.Sh. Mirzakhodjaev, A.M. Tursunov, Republican scientific-practical conference. A collection of articles, 57-61 (2022)
5. N. Namozov, M. Saidova, M. Urmanova et al, IOP Conference Series: Earth and Environmental Science **1068(1)**, 012035 (2022)
6. Z. Abdullaev, D. Kendjaeva, S. Xikmatullaev, International Conference on Information Science and Communications Technologies (ICISCT) (2019)
7. G. Shodmonova, U. Islomov, O. Abdisamatov, S. Khikmatullaev, U. Kholiyorov, S. Khamraeva, IOP Conference Series: Materials Science and Engineering **896(1)**, 012117 (2020)
8. P. Charzyński, M. Urbańska, G.F. Capra et al, Geoderma **425**, 116053 (2022)
9. U. Makhmudova, A. Djuraev, T. Khushvaktov, IOP Conference Series: Earth and Environmental Science **937(3)**, 032024 (2021)
10. B. Matyakubov, G. Goziev, U. Makhmudova, E3S Web of Conferences **258**, 03022 (2021)
11. S. Isaev, A. Mambetnazarov, B. Khalmuratova, G. Goziev, Y. Ashirov, IOP Conference Series: Earth and Environmental Science 1068(1), 012044 (2022)

12. A. Shamsiev, S. Isaev, G. Goziev, S. Khusanov, N. Khusanbaeva, IOP Conference Series: Earth and Environmental Science **1068(1)**, 012025 (2022)
13. Z.J. Khudoyorov, International scientific journal "Science and Innovation". Special issue "Sustainable forestry". Science and Innovation, 433-437 (2022)
14. Z.J. Khudoyorov, Bulletin of Agrarian Science of Uzbekistan **5(5)**, 186-189 (2022)
15. N. Eshpulatov, T. Khalmuradov, R. Khalilov et al, E3S Web of Conferences **264**, 04072 (2021) https://doi.org/10.1051/e3sconf/202126404072
16. F. Mamatov, Sh. Mirzakhodjaev, B. Khudoyarov, U. Kuziev, A. Rajabov, Agriculture of Uzbekistan **3(3)**, 42-43 (2007)
17. F.M. Mamatov, I.T. Ergashev, B.S. Mirzaev, Sh. Mirzakhodjaev, Selsky is a mechanic **10**, 10-11 (2011)
18. Sh. Mirzakhodjaev, A. Beknazarov, J. Yoldashov, Agro science **6(44)**, 76 (2016)
19. A. Jahangirov, Sh. Mirzakhodjaev, A. Artykov, Agriculture of Uzbekistan **11**, 39 (2016)
20. F.M. Mamatov, I.T. Ergashev, S.S. Mirzaxodjaev et al, European science review **3-4**, 264-266 (2018)
21. F. Mamatov, Sh. Mirzakhodjaev, Agro science **6(56)**, 94-95 (2018)
22. U. Uzbekov, B. Pulatov, B. Alikhanov, A. Pulatov, GeoScape **15(2)**, 159-172 (2021)
23. D. Kadirova, M. Usmanova, M. Saidova, G. Djalilova, N. Namozov, E3S Web of Conferences **258**, 03025 (2021)
24. R. Kulmatov, S. Odilov, S. Khasanov, R. Allaberdiev, E3S Web of Conferences **284**, 01015 (2021)
25. B. Mirzaev, F. Maмatov, I. Ergashev et al, E3S Web of Conferences **135** (2019)
26. A.A. Akhmetov, F.M. Mamatov, A.O. Aripov et al, Innovative technologies **4(36)**, 77-80 (2019)
27. Sh.Sh. Mirzakhodjaev, A. Mamasov, Kh. Shodiev, I.Kh. Yakshamurodov, Journal of science and education **6(84)**, 15-17 (2020)
28. K. Shodiev, S. Mirzakhodzhayev, Journal of Agro Processing **6(2)**, 26-29 (2020)
29. S.S. Mirzakhodjaev, K.B. Shodiev, A.A. Mamasov, R.T. Akhmedov, Application of Science for Sustainable Development to Overcome Covid-19 Pandemic **9**, 286-289 (2020)
30. A.J. Beknazarov, B.U. Nurmikhamedov, S.A. Mamasov, S.S. Mirzakhodjaev, International Journal of Progressive Sciences and Technologies (IJPSAT), 101-103 (2020)
31. S. Mirzaxodjaev, Innovative energy & Research **9(4)**, 141-145 (2020)
32. F. Mamatov, B. Mirzaev, Sh. Mirzahodzhaev, Z. Uzakov, D. Chorieva, IOP Conf. Series: Materials Science and Engineering **1030**, 012164 (2021) https://iopscience.iop.org/article/10.1088/1757-899X/1030/1/012164
33. S. Mirzakhodjaev, K. Shodiev, G. Uralov et al, E3S Web of Conferences **264**, 04047 (2021) https://doi.org/10.1051/e3sconf/202126404047
34. Sh. Mirzaxodjaev, F. Mamatov, A. Mamasov, I.KH. Yakhshimurodov, S. Yuldoshev, Journal of Current Engineering and Technology **3(1)**, 136 (2021)
35. KH.B. Shodiev, SH. Mirzakhodzhaev, A. Zhakhongirov, Journal of Current Engineering and Technology **3(1)**, 133 (2021)

36. B.S. Khodzhimurod, J. Abdurashit, S.M. Sherzodkhuja, Scientific progress **3(3)**, 251-256 (2022)
37. S.E. Nizkii, A.A. Muratov, Y.A. Gavrilov, G.A. Gavrilova, IOP Conference Series: Earth and Environmental Science, **677**, 042028 (2021), doi:10.1088/1755-1315/677/4/042028
38. S. Nizkiy, A. Muratov, E3S Web of Conferences, **203**, 02005 (2020), https://doi.org/10.1051/e3sconf/202020302005
39. Sh. Mirzakhodjayev, A. Jakhongirov, H. Shodiyev, A. Mamasov, Agriculture and Water Management of Uzbekistan **6**, 36-37 (2022)
40. A.A. Ahmetov, H.K. Atakulov, M.A. Allanazarov, I.A. Inojatov, B.U. Nurmihamedov, Zh.K. Uzakbergenov, *Comprehensive research on the creation of combined tillage machines* (Buhoro, 2012).