საქართველოს მეცნიერებათა ეროვნული აკადემიის მოამბე, ტ. 17, №4, 2023
BULLETIN OF THE GEORGIAN NATIONAL ACADEMY OF SCIENCES, vol. 17, no. 4, 2023

Hydrology

Calculation of the Main Hydrological Parameters of Regime for Irrigation Areas

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Innovative models of appropriate operational methods for liquids are considered in the present paper. The risks posed by the climate change in agriculture have significant impact on irrigation. In choosing the irrigation areas with the aim to increase crop yields, a number of interconnected factors must be taken into account. Wide range of physical and chemical processes occurring in soil fundamentally affects its fertility and potential, filtration and capillary capacity and the dynamics of changing moisture content. The problem is equally actual both for arid and swampy soils. Particularly noteworthy is the influence of mineralization of soil and its hard soluble substances on the speed of chemical and biological processes of plant growth and development. The speed is directly related to the resistance of constituent minerals and hard soluble substances of soil. Certain influence on soil fertility is exerted by plant uptake of food from soil, rates of microorganism development and chemical and biological processes. Water consumption for irrigation is related to water supply parameters and soil characteristics on irrigation areas. In the model of plant growth-development particular attention is paid to the irrigation regime. The irrigation regime is directly related to soil and ground parameters. Due to the complexity of the issue, the factors related to the irrigation process in the zone of complete soil saturation and aeration are thoroughly taken into account. Based on the generalized model of the new relations of hydrology and hydraulics, the distribution of irrigation water on the irrigation areas without losses is considered. In order to mitigate irrigation erosion processes, new calculation relations are derived. *© 2023 Bull. Georg. Natl. Acad. Sci.*

irrigation area, irrigation regime, irrigation rate, water infiltration, soil, ground, porosity, erosion, moisture

Moisture regulation in the soil-ground body owing to anomalous and multicomponent nature of the complex processes occurring in it, is viewed as a complex problem. Soil characteristics play an important role in this process. Micro- and macro-structure of soil is important for the process of water movement and migration what affects the relative deformation and often leads to the violation of the linear law of filtration, but does not determine soil potential.

When soil is a highly dispersed hydrophilic system, a boundary layer with complex properties is formed between its separate parts by energy fields. In such a case, the general understanding of soil and ground is focused on other characteristics, such as filtration, thickness as a parameter defining it, filtration ratio, water infiltration, etc. During the evaluation of these characteristics, priority is given to structural characteristics of soil. Change of quantitative values of presented characteristics determines the soil properties, in particular migration in its body, and has a special function in selecting both reclamation regime (irrigation and drainage) and hydrological characteristics. As for surface phenomena, i.e. capillary phenomena in the given case, the focus is placed on dispersion [1-3].

When reviewing the model of plant growth and development in irrigation agriculture, the irrigation regime, stable water supply with standard irrigation rate and without losses, are particularly important. The optimum management of irrigation regime depends on these and soil and ground parameters. Accuracy of their registration depends on the accuracy of the used operational methods [2-6].

Due to the complex nature of soil moistening, the available calculation models fail to thoroughly assess such parameters, as complete saturation of reclaimed lands as well as physical, mechanical and biological processes and natural and climatic properties of soils in the aeration zone.

In hydromelioration the main requirement for irrigation and drainage is the distribution of irrigation water over the area with uniform intensity, as well as proper water management and regulation. Water distribution on the irrigated area depends on the topography of the terrain surface, hydrological conditions, distribution of plants in the area, accuracy of the regulation technique, plant biology and the use of agricultural technique [1-8].

The necessity of water regime management in agriculture depends on water requirements, evaporation and evapotranspiration abilities of plants.

Water absorption from the surface by soil takes place according to the principle of equal infiltration in accordance with the prescribed condition. The curvilinear shape of water distribution on the plot surface and the possibility of water infiltration into the soil with uniform intensity along the section are adapted to the water absorption model. At the beginning of plot, when irrigation water is supplied at the depth of h and supplied water is distinguished by its density and peculiar pattern of changes of its parameters, the average velocity in the area is taken as the characteristic parameters of fluid movement over the area. Using the average velocity model $v = ch$ tested in hydraulics, the specific value of irrigation flow supplied to the area is calculated by the following formula

$$q = ch^2 f(\beta). \quad (1)$$

$$f(\beta) = \psi^2\left[1 - \sqrt{1-m}\left(1{,}5 - 0{,}5\sqrt{1-m}\right)\right]$$

and $V = ch = \frac{\gamma i h^2}{3\mu}$ in the given calculation model, where γ is volume mass of liquid (N/m^3); I is slope of irrigation area surface; h is depth of liquid supply at the initial section (m); μ is viscosity factor, N.s/m^2; m is porosity coefficient; ψ is internal friction coefficient; and c is velocity coefficient, m$^{1/2}$/s.

The difference between the discharges of the sections selected according to the calculation model is

$$YV_x - Y^1V_x^1 = -2Ycf(\beta)dY. \quad (2)$$

Following relation (2), the difference between the discharges along section dx is due to water infiltration. To estimate the liquid flow rate along the soil strip with the width of B and length of L in time t, the approved calculation models of the relation between filtration and time are used in the present paper [1], while the energy of water remaining on the ground surface is estimated by correction coefficient n. The value of the correction coefficient depends on whether the soil structure may be disturbed [9,10].

When the depth of current at the beginning of the area surface is $h = \sqrt{(q/c)}f(\beta)$, value h along X strip is the greater, the greater the surface alimentation (discharge) is and the lesser the thickness and slope are. By adjusting the average rate of fluid infiltration into the soil along X section of the water strip with the width of B, the relationship between the discharge of water layer remained in time t and the infiltration can be estimated using the following equation

$$2cYdY = -\frac{nK_0}{t^\alpha f(\beta)}dx, \quad (3)$$

where c is liquid velocity coefficient, $m^{1/2}/s$; K_0 is infiltration coefficient, m^2; t is time of water infiltration into soil, s; α is quality index and depends on soil type; $f(\beta)$ is coefficient and depends on soil structure; Y and X are coordinates of free surface of moving liquid.

By integrating relation (3)

$$q = \frac{nK_0X}{t^\alpha f(\beta)}. \quad (4)$$

Relation (4) can be used to assess both the length of the irrigation zone with the width of 1 m and t time of water infiltration into the soil

Flow length

$$X = \frac{qt^\alpha f(\beta)}{nK_0}. \quad (5)$$

Flow time

$$t = \left(\frac{nK_0X}{f(\beta)}\right)^{\frac{1}{\alpha}}. \quad (6)$$

Similarly, the change of q_x discharge of free surface of liquid along X line is

$$q_x = q\left(1 - \frac{nK_0X}{qt^\alpha f(\beta)}\right). \quad (7)$$

By analyzing relation (7), the member on the right given in brackets is percentage of the part of water to discharge moving on surface of area. If denoting this value by Y_0 , the folowing equation will be obtained

$$Y_0 = 1 - \frac{nK_0X}{qt^2 f(\beta)}. \quad (8)$$

By analyzing relation (8), the possibility of water outflow from an irrigated area by increasing the discharge of water to supply increases during the outflow and the more stable the soil is and the greater the leakage ratio is, the lesser the percentage of outflow is.

According to field studies, when irrigation stops, the length of the irrigation zone increases and water from depth h decreases to 0. In addition, the volume of water remaining on the surface of the irrigation area is a part of the volume of supplied water. If denoting this value by M, it changes within the limits of (2/3÷4/5). Based on the calculation model, the water remained on the surface is absorbed along distance X and the remained water flows beyond zone X, along $(l - X)$ section of outflow from its boundaries. Following the need for the uniform moistening when the volume of water remaining on the surface of the area is assumed to be lossless, the amount of water absorbed at the depth can be estimated by value $(1 - a)hx$. The possibility of outflow of the water remaining in zone X can be estimated by equation

$$(l - x)m = MhX - (1 - a)hX. \quad (9)$$

By considering the change of value M in equation (9), when the following equation is obtained

$$l = \frac{qt^2}{nK_0}\frac{h}{m}\left(a - \frac{1}{3}\right)f(\beta). \quad (10)$$

The value of irrigation rate without water discharge for 1 m wide irrigation zone is calculated by formula

$$N = \frac{nK_0}{\psi^2 t^{\alpha-1}\left(a-\frac{1}{3}\right)\left[1-\sqrt{1-m}\left(15\sqrt{1-m}\right)-0,5\right]}. \quad (11)$$

As for the irrigation purposes, the use of full water potential without discharge is considered, i.e. Nn=Nbr

$$\frac{K_0t^{1-\alpha}}{f(\beta)} = \frac{qt}{x}. \quad (12)$$

The amount of water to supply to the area, by considering irrigation rate N, is

$$Q = \frac{m\omega}{tf(\beta)} = \frac{m\omega}{t\psi^2\left[1-\sqrt{1=m}\left(1,5\sqrt{1-m}-0,5\right)\right]}. \quad (13)$$

Duration of irrigation is

$$t = \frac{m}{K_{saS.}} = \left(\frac{nf(\beta)}{K_0}\right)^{\frac{1}{1-\alpha}}. \quad (14)$$

When irrigation flow is $Q = Bch^2$, permissible flow rate is $V_0 = ch$ and scouring velocity changes within $V = 0,1 \div 0,2$m/s, the soil non-scouring state condition is determined by inequality

$$\frac{m\omega}{t\psi^2\left[1-\sqrt{1-m}\left(1,5\sqrt{1-m}-0,5\right)\right]} \leq \frac{BV_0^2}{c}. \quad (15)$$

Inequality (15) can be used to assess soil scouring value and possibility of expected development of irrigation erosion.

Conclusions

The relationship between the size of an irrigation area and irrigation flow potential is determined. By considering the possibility of full water use, the model is selected, which takes into account the possibility of change of water flow regimes on the irrigation areas, supply of the necessary amount of water to irrigation fields by uniform distribution.

The type of formation of free surface of the irrigation water moving in the area depending on water flow rate and time, water infiltration, as well as physical and mechanical characteristics of the soil is evaluated.

In order to irrigate the areas without losses, completely new relation to calculate irrigation rate is developed. Taking into account the anomalities, the ranges and opportunities to change irrigation water amount are specified.

ჰიდროლოგია

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§ საქართველოს ტექნიკური უნივერსიტეტი, აგრარული მეცნიერებების და ბიოსისტემების ინჟინერინგის ფაკულტეტი, თბილისი, საქართველო

კლიმატის ცვლილებით შექმნილი რისკები სოფლის მეურნეობაში არსებით გავლენას ახდენს სარწყავ მიწათმოქმედებაზე. სოფლის მეურნეობის კულტურების მოსავლიანობის გაზრდისათვის სარწყავი ფართობის შერჩევა მრავალი ურთიერთმართვადი ფაქტორის გათვალისწინებას საჭიროებს. ნიადაგ-გრუნტში მიმდინარე ფიზიკურ-ქიმიური პროცესების ფართო სპექტრი რადიკალურად ცვლის მის ნაყოფიერებას, პოტენციალს, ფილტრაციულ-კაპილარულ შესაძლებლობებს, ტენის ცვალებადობის დინამიკას და ნიადაგის ნაყოფიერების მაჩვენებლებს. აღნიშნული პრობლემა თანაბრად აქტუალურია როგორც არიდული, ისე დაჭაობებული ნიადაგისათვის. განსაკუთრებით აღსანიშნავია ნიადაგის მინერალიზაციისა და შემადგენელი ძნელად ხსნადი ნივთიერების გავლენა-ზემოქმედება მცენარის ზრდა-განვითარებაში მიმდინარე ქიმიურ-ბიოლოგიური პროცესების სისწრაფეზე. იგი უშუალოდაა დაკავშირებული შემადგენელ მინერალებსა და ძნელად ხსნად ნივთიერებათა მდგრადობასთან. აღნიშნულიდან გამომდინარე, მცენარის მიერ ნიადაგიდან საკვების შეთვისება, მიკროორგანიზმების, ქიმიურ-ბიოლოგიური პროცესების განვითარების სისწრაფე გარკვეულ გავლენას ახდენს ნიადაგის ნაყოფიერებაზე. ირიგაციაში წყალხარჯვა სარწყავ ფართობზე წყლის მიწოდების პარამეტრებსა და ნიადაგის მახასიათებლებთანაა დაკავშირებული. მცენარის ზრდა-განვითარების მოდელის განხილვის დროს განსაკუთრებული ადგილი რწყვის რეჟიმს ეთმობა. აღნიშნული რეჟიმი ნიადაგ-გრუნტის პარამეტრებთანაა უშუალო კავშირში. ამ მიზნით ნაშრომში შემოთავაზებულია სითხეებისათვის შესაბამისი ოპერატიული საშუალებების ინოვაციური მოდელები. საკითხის სირთულიდან გამომდინარე, სრულყოფილადაა გათვალისწინებული მორწყვის პროცესთან დაკავშირებული ფაქტორები ნიადაგის სრული გაჯერებისა და ჰაერაციის ზონაში. ჰიდროლოგიისა და ჰიდრავლიკის საანგარიშო ახალი დამოკიდებულებების განზოგადებულ მოდელზე დაყრდნობით გათვალისწინებულია სარწყავ ფართობებზე წყლის დანაკარგების გარეშე განაწილება. ირიგაციული ეროზიული პროცესების შესუსტების მიზნით გამოყვანილია ახალი საანგარიშო დამოკიდებულებები.

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Received April, 2023