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Research Article

Increasing Efficiency of Water Resources Use in Forage Crops Irrigation

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ABSTRACT:
The Saratov region is among areas where restoration and developing agriculture is actively conducted. Ameliorative complex condition is an important component of the modern agro-industrial sector of Russia. Currently the Saratov region receives more funds for melioration from the federal budget, than others. During restoration of the reclaimed lands the area faces problems. Along with increase in crop productivity due to irrigation, there is deterioration in soil fertility. The raising level of ground waters results in threat of secondary salinization of soils. In this regard it is necessary to provide an integrated approach to land reclamation which is based on the analysis of melioration development in various agro-climatic zones of the Saratov Zavolzhye. This approach provides developing resource-saving, nature protection, ecologically safe technologies of land reclamation, including rationingg of the crop irrigation mode. Therefore the need to increase the efficiency of irrigating water use evolved from adaptation of model and the program of adaptive rationingg of lucerne irrigation for conditions of dry steppe Zavolzhye. Theoretical and pilot researches of the factors influencing the crop water consumption were conducted, the model of irrigation rationingg on dark-chestnut soils of the Saratov Zavolzhye for lucerne culture have been adapted. Power efficiency of lucerne cultivation with application of the program of irrigation adaptive rationingg which showed decrease in expenses of irrigation water by 10% is defined.
Keywords: Efficiency, water, irrigation, culture, factor, water consumption, adaptation, program, validation, approbation.

1. INTRODUCTION

Dry steppe Zavolzhye is in a zone of risky agriculture and cultivation of crops in this zone is impossible without irrigation. At the same time broad developing irrigation in the eighties of the last century led to sharp deterioration in ecological situation in the region [1-3, 17]. As of 2014 the total area of the irrigated lands of the Saratov region makes 257,3 thousand hectares, from them 58,15 thousand hectares are ineffective: 3,75 thousand hectares have the level of ground waters less than 3 m from surface; 14,9 thousand hectares are poorly, average and heavily cindered; 39,5 thousand hectares of soils are average and strongly alkali. Along with it efficiency of the irrigated hectare remained lower than potentially possible, without exceeding 3,7 t/hectare k.a. The reason of the developed adverse condition of irrigation lands and low productivity of the irrigated cultures is insufficiently perfect irrigation rationing at which defining total water consumption is carried out only taking into account biological properties of culture and meteo-conditions. Use of such model according to influence of moisture security of the agricultural field on the volume of total water consumption is directed to obtaining the maximum productivity and leads to an excessive water consumption. Adaptive irrigation rationing is based on defining total water consumption taking into account the developing water mode of the soil, condition of an active surface, meteo-conditions and biological features of culture in the course of ontogenesis and directed to obtaining the set productivity. The main fodder culture cultivated in the conditions of irrigation of dry steppe Zavolzhye is the lucerne which has valuable biological and fodder advantages: the nitrogen-fixing ability allowing to lower chemical load of the soil; high efficiency; balance of a forage; it can be used on hay, green material, haylage, grass meal. Lucerne cultivation helps to solve not only a fodder problem, but also a problem of increase in fertility of the soil, protection of soils against wind and water erosion therefore it is most important to improve irrigation rationingg of this culture.

2.RESEARCHE TECHNIQUE

2.1.Research of the factors influencing total water consumption

Total crop water consumption is the function of weather conditions, moisture contents of the soil and biological properties [8] of culture which is described by the following function:

$$ET = f(E, W, B) \quad (1)$$

where: *ET* - total water consumption, mm; *E* - the evaporability characterizing weather conditions, mm; *W* - moisture contents in the soil, mm; *In* - biological properties of culture.

First of all water consumption depends directly on evaporability. Use of evaporability in calculations of crop water consumption demands the choice of the most exact technique most of which really reflect process of evaporation from the irrigated field spreading surface qualitatively changes during the period of crop vegetation. Widespread techniques of defining evaporability are N. N. Ivanov's technique and a Budyko-Zubenok method.

According to N. N. Ivanov [7] recommendations evaporability (mm/month):

$$E = 0{,}0018(25+t)^2(100-\varphi) \quad (2)$$

where: t - air temperature, 0C; φ - relative air humidity, %.

For defining evaporability by a Budyko-Zubenok method, curvilinear dependences (figure 1) of evaporability on deficiency of air humidity *(dφ)* on months which are described by the following equation were used [15]:

$$E = ad_{\varphi}^{3} - bd_{\varphi}^{2} + cd_{\varphi} + k \quad (3)$$

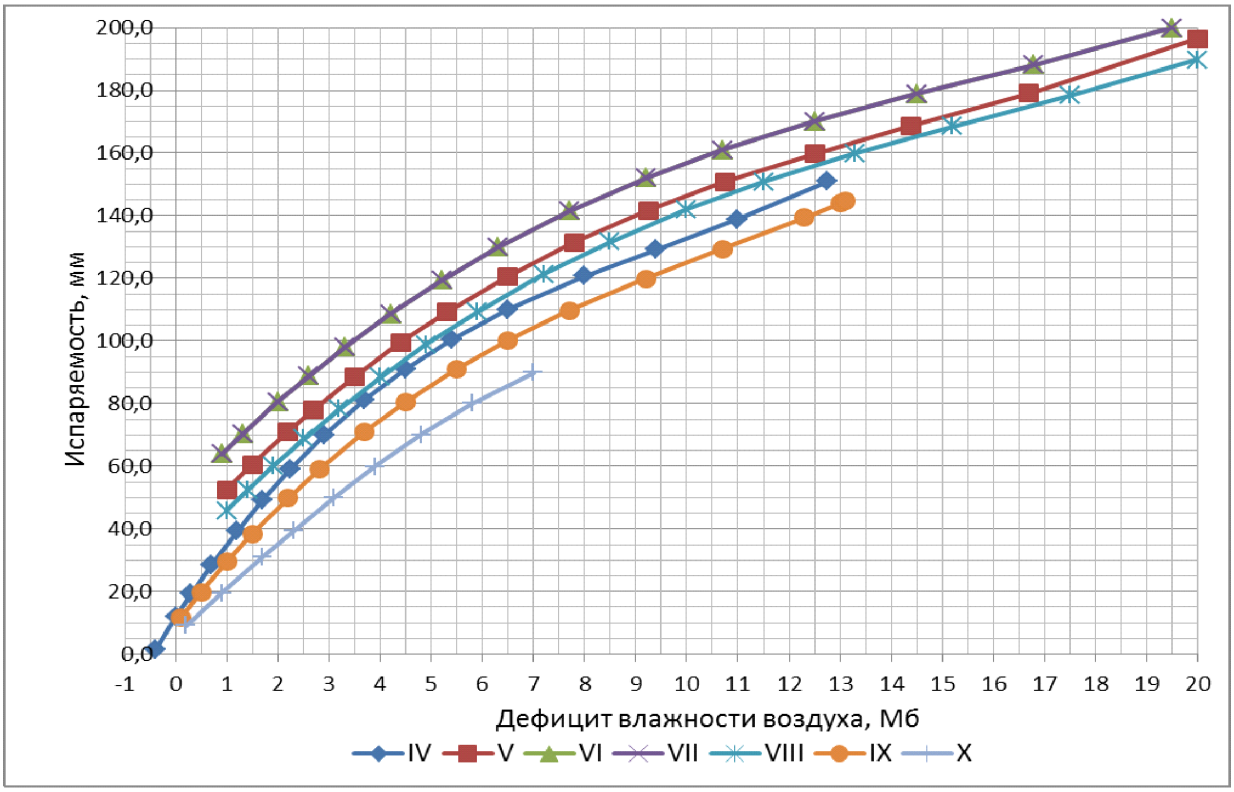
where: E - evaporability, mm; $d\varphi$ - deficiency of air humidity, MB.

Approximation of dependence (3) allowed to define empirical coefficients of a, b, c, k for conditions of dry steppe Zavolzhye (table 2.1).

Table 2.1 - Empirical coefficients for calculation of evaporability for a Budyko-Zubenok method

Period				
01.04–30.04	,069	,003	5,19	1,90
01.05–31.05	,021	,921	8,30	5,06
01.06–31.07	,017	,836	7,43	8,89
01.08–31.08	,017	,841	8,03	8,65
01.09–30.09	,043	,395	1,18	,58
01.10–31.10	,033	,223	5,18	,05
R^2=0,99				

The evaporability according to recommendations about calculation of evaporation from a land surface has the following dependences on deficiency of moisture and temperature which corresponds to a certain interval of time (month) (figure 1):



1. Испаряемость, мм	1. Evaporability, mm
2. Дефицит влажности воздуха, Мб	2. Deficiency of air humidity, MB

Fig. (1). The schedule of evaporability dependence on air humidity deficiency for a steppe zone on months of year

During crops of lucerne before growth the spreading surface can be characterized as the open surface of the soil, but further on the course of growth and developing community of plants there is a high-quality change of a condition in active surface of the soil. Key parameters, when rationingg irrigation and obtaining necessary productivity, are soil moisture contents which have to be in certain limits during all vegetative period of culture [9]. The actual humidity of an earth layer is defined by practical consideration, on further interpolation of humidity volumes of the soil for every day, considering the mode of loss of rainfall, watering and average value of moisture contents for the considered time interval equal to decade finally is determined by them. Biological properties of culture, depend on a type of culture *To*, grades of *S* and a growth phase and cultural development *F [8]*:

$$B = f_1(K, S, \Phi) \qquad (4)$$

For specific culture, *K - const* and a grade *of S - const* change of biological properties of culture will take place on growth phases and development, i.e.

$$B = f_2(k_б) \qquad (5)$$

It is known that the bioclimatic coefficient (k_b), takes various values according to growth phases and developing specific culture.

The equation of dynamics of the water mode for certain ground layer has an appearance:

$$W_к = W_н + P + \sum m \pm q - ET \qquad (6)$$

where: W_k - soil moisture contents for the end of the certain period, mm; W_n - soil moisture contents for the beginning of the certain period, mm; *P* - atmospheric precipitation, mm; *Σm* - the sum of irrigation norms, mm; *q* - an indicator of moisture exchange of an active ground layer with the spreading soil, mm.

The model developed for conditions of dry steppe Zavolzhye, considering the developing water mode of the soil, meteocondition, biological features of culture and a condition of an active surface S. V. Zatinatsky's model according to which total water consumption determined by dependence [6, 12] is:

$$ET = \frac{E \cdot A_n}{\left(1 + 10^{\gamma - \beta \frac{W_{act} - W_{pwp}}{W_{FC} - W_{pwp}}}\right)} \quad (7)$$

where ET - total water consumption, mm; E - evaporability, mm; W_{act} - the actual moisture contents, mm; W_{PWP} - the soil moisture contents corresponding to humidity of withering, mm; W_{FC} - the soil moisture contents corresponding to the smallest moisture capacity, mm; A_n, γ and β - the empirical coefficients defining a condition of an active surface and biological features of culture in the course of ontogenesis:

$$\beta = \frac{\frac{\sum\left(lq\frac{A_n}{ET/E} - 1\right) \cdot \sum W}{n} - \sum W \cdot lq\left(\frac{A_n}{ET/E} - 1\right)}{\frac{\left(\sum W\right)^2}{n} - \sum W^2} \quad (8)$$

$$\gamma = \frac{\sum lq\left(\frac{A_n}{ET/E} - 1\right) - \sum W \cdot \beta}{n} \quad (9)$$

Value of empirical coefficients is defined at $\frac{ET}{E} < A_n$ where n - quantity of the relations *of ET/E.*

Productive moisture contents of the soil, are expressed in shares on dependence:

$$\overline{W_{act}} = \frac{W_{acti} - W_{pwp}}{W_{FC} - W_{pwp}} \quad (10)$$

where: W_{acti} - the actual moisture contents of the soil, mm; W_{PWP} - the soil moisture contents corresponding to humidity of withering, mm; W_{FC} - the soil moisture contents corresponding to the smallest moisture capacity, mm.

Total water consumption by A. M. Alpatyev [4] method will be expressed:

$$ET = k_б \cdot \sum d_\varphi \quad (11)$$

where: ET - total water consumption, mm; k_b - bioclimatic coefficient, mm/MB; $\Sigma d\varphi$-sum of average daily deficiencies of air humidity, MB.

According to dependence (7) and defining total water consumption on A. M. Alpatyev (11) model dependence for defining coefficient of a condition of an active surface is received:

$$A_n = \frac{k_б \cdot \sum d_\varphi \cdot \left(1 + 10^{\gamma - \beta \cdot \overline{W_{act}}}\right)}{E} \quad (12)$$

where: A_n, γ and β - the empirical coefficients determining a condition of an active surface and biological features of culture by the vegetation periods; k_b - bioclimatic coefficient, mm/MB; $\Sigma d\varphi$ - the sum of average daily deficiencies of air humidity, MB; $\overline{W_{act}}$ - relative productive moisture contents of the soil, %.

Using experimental data on lucerne water consumption, it was defined how for the periods of lucerne vegetation dependence *of ET/E* will be defined on relative productive moisture reserves in the soil. The received curvilinear dependence is described by the equation of the following look [5, 13, 11]:

$$ET / E = A_n / \left(1 + 10^{\gamma - \beta \cdot \overline{W_{act}}}\right) \quad (13)$$

where: *ET/E* - the relation of total water consumption to evaporability, mm; A_n, γ and β - the empirical coefficients determining a condition of an active surface and biological features of culture by the vegetation periods; $\overline{W_{act}}$ - relative productive moisture contents of the soil, %.

At maintenance in an estimated ground layer of humidity:

$$W_{act} = (W_н + W_к)/2 \geq W_{FC} \text{ member } (W_н + W_к)/2\gamma = 1 \quad (14)$$

Therefore, on condition of $W_{act} < W_{FC}$ the defining value when forming the crop water consumption will have soil moisture contents, at W_{act} □ W_{FC} water consumption is defined by tension of weather conditions. The lower bound of optimum moisture contents range of the soil *(Wact)* for plants are critical moisture contents *(Wcr)* and the admissible threshold of the soil siccation corresponding to them: at $W_{act} = W_{cr}$ at which achievement the culture slows down growth and reduces the efficiency. The upper bound of optimum humidity for plants is the maximum humidity and a reserve of moisture which corresponds to the smallest moisture capacity of the soil (a full field moisture capacity) *of WFC*, when moistening the soil above which excess of moisture gives to washing away of plants, soil erosion, replenishment of ground waters and decrease in fertility of lands. Therefore the maximum irrigation norm in mm, should not exceed the size of humidity of the smallest moisture capacity [10]:

$$m_{nt} = 100 \cdot h_w \cdot \rho \cdot (\omega_{FC} - b \cdot \omega_{cr}) \quad (15)$$

where: m_{nt} - certain irrigation norm, mm; h_w - the certain saturation depth of the soil, m; ρ - density of addition of the soil, t/m^3; ω_{FC} - humidity of the soil corresponding to the smallest moisture capacity, % to weight; ω_{cr} - the humidity corresponding to an admissible threshold of a siccation and equal to $b \cdot \omega_{FC}$, % weight; *b* - depending on particle size distribution of the soil (for loamy and clay soils 0,75 … 0,8) [18]. From the equation (15) the size of irrigation norm depends on a layer of moistening (h_w), and a pre-irrigation threshold of humidity (ω_{cr}).

Support of moisture reserves in an active ground layer within optimum range has to come from observance of a condition:

$$W_{FC} \geq W_{act} \text{ □ } W_{cr} \quad (16)$$

At such maintenance of moisture reserves according to expression (16) minimization of losses of water and optimum moisture ensuring culture will be provided.

Optimum control of irrigation has to be directed to realization of such norms and terms of watering at which more favorable distribution of the available water resources focused on obtaining the maximum effect of irrigation will be reached.

2.2. Application of mathematical irrigation rationingg model to increase efficiency of water resources use

The high-perspective solution of environmental problems on the irrigated lands is application of information systems and mathematical models on the basis of computer programs. Defining total water consumption of culture taking into account formation of the water mode of an estimated ground layer, meteo-environmental conditions, conditions of an active surface of the soil and biological features of culture on the vegetation periods is the basis for the adapted model of irrigation rationing. On the basis of the offered model (7) the program of adaptive irrigation rationing for lucerne in the Visual Basic 2012 (PRNOSK) programming language was created. As a development environment Microsoft Visual Studio 2012 Express which can be used on PC under control of the Windows 2003-2012 operating system was used. The main procedure and the program of lucerne irrigation rationing, screen forms with the built-in user procedures, including windows of initial parameters input, a window of input for additional parameters, a viewport and deliveries of calculation results is a part of the software.

The algorithm of the program consists in daily definition of all indicators for adaptive lucerne irrigation rationing for all vegetative period [14]. In model it is possible to allocate 3 types of data: 1 - entered manually (the figure 2 (windows are highlighted in white color)), 2 – calculated automatically on the set algorithm (the figure 2 (windows are highlighted in gray color)), 3 - the graphic part automatically built based on this 2 look (date of the vegetative period and moisture reserves in the soil).

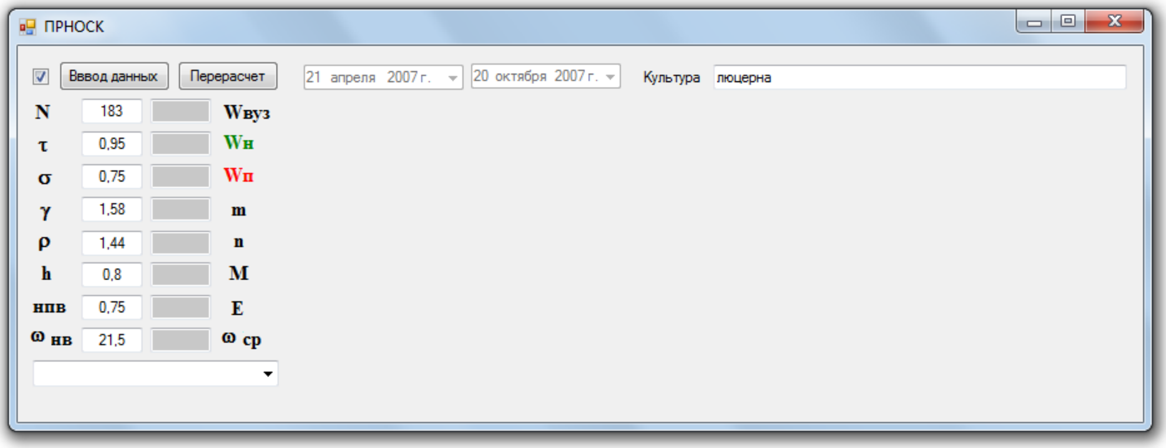


Fig. (2). Data input window

The following basic data are necessary for work of model: daily meteo-information: average daily air temperature *(t)*; relative air humidity *(φ)*; the sum of an atmospheric precipitation during the day *(P)*; deficiency of air humidity *(dφ)*; duration of the culture vegetative period *(T)*; number of growth phases and cultural development *(Φ)*; an estimated ground layer *(hw)* in which the bulk of culture roots is widespread; humidity of withering (ωPWP); the humidity corresponding to the smallest moisture capacity $_{\omega FC}$; the top threshold of moistening (τ) and a pre-irrigation threshold (σ) are set in shares (0-1); bioclimatic coefficient *(kb)*; condition of an active surface of the soil *(An)*; the empirical coefficients determining biological features of culture by the vegetation periods (*γ* and *β*); admissible threshold of siccation (ωcr); density of the soil addition *(ρ)*. Additional data for adaptive lucerne irrigation rationing are entered into the "Input of Additional Data for Calculation" window (figure 3). As a result of adaptive lucerne irrigation rationing on the set algorithm the following indicators stand: *W*-moisture contents of the soil, mm; *E* - evaporability, mm; *ET* - the total water consumption of culture; *m* - irrigation norm; *n* - watering quantity; *M* - irrigating norm are also established days of carrying out watering, according to a graphic part of the program.

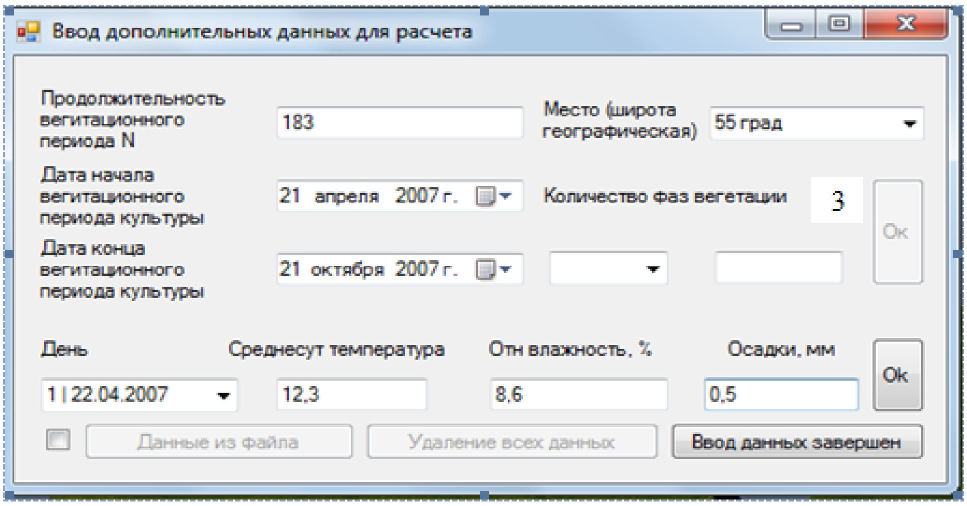


Fig. (3). Window of additional data input

Graphic part of the adaptive irrigation rationing program consists of the dynamics schedule for moisture contents of the soil which is built automatically on the course of all vegetative period of culture (figure 4).

Fig. (4). Window of results delivery for modeling of lucerne irrigation rationing.

The developed program of adaptive lucerne irrigation rationing allows receiving irrigation rationing indicators quickly: culture water consumption for the vegetative period, size of irrigating norm, irrigation norm, terms of carrying out watering and the quantity. The program is focused for specialists of separate farms and irrigating systems for developing plans of water use and applications for water.

The certificate on the state registration of the computer program No. 2015661256 in Federal State Budgetary Institution Federal Institute of Industrial Property of 22.10.15, Moscow (the application No. 2015618158 of 08.09.2015) is received [16].

3. RESULTS.

Validation of the adaptive lucerne irrigation rationing program "PRNOSK" consisted in quantitative assessment of model compliance to the object set for it. For validation experimental data of observations for the modeled object were used. The result of lucerne irrigation rationing modeling for one of the research hyears is presented in the figure 5.

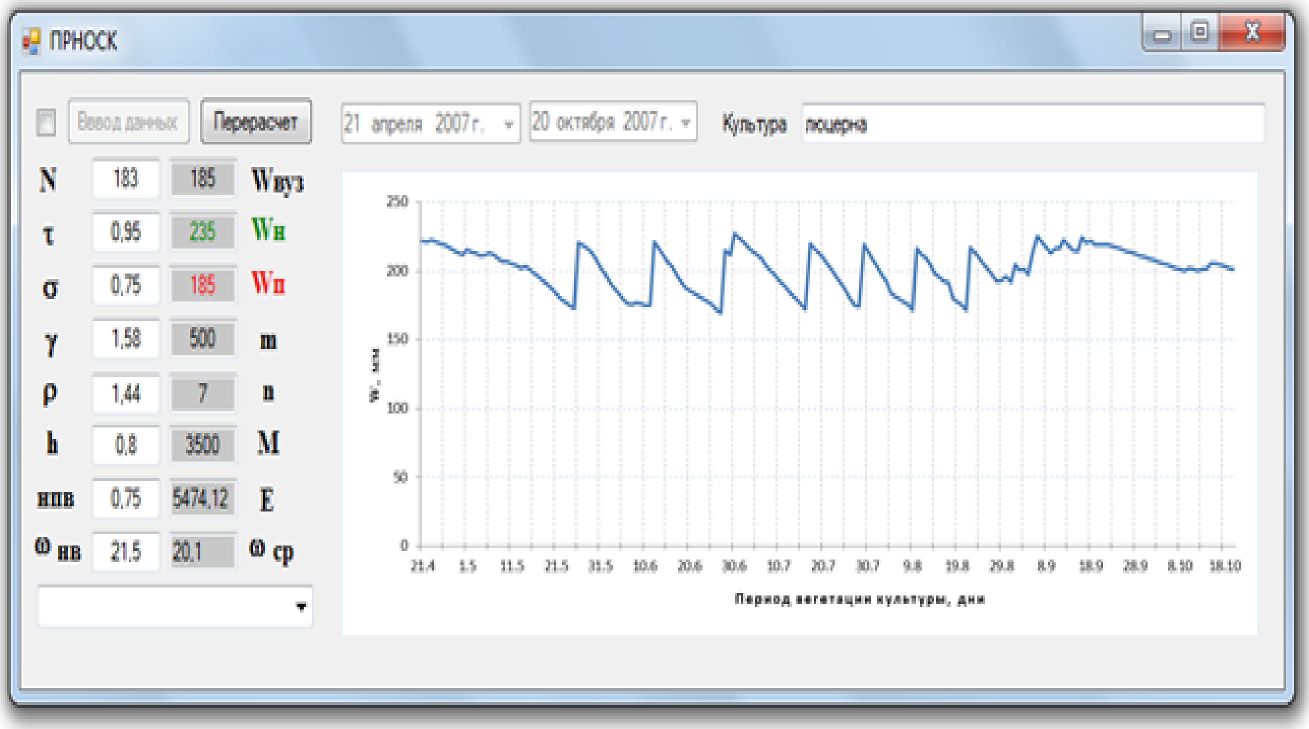
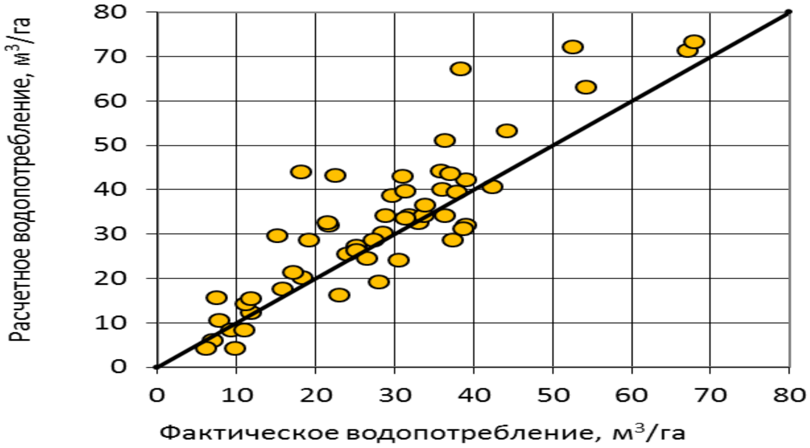


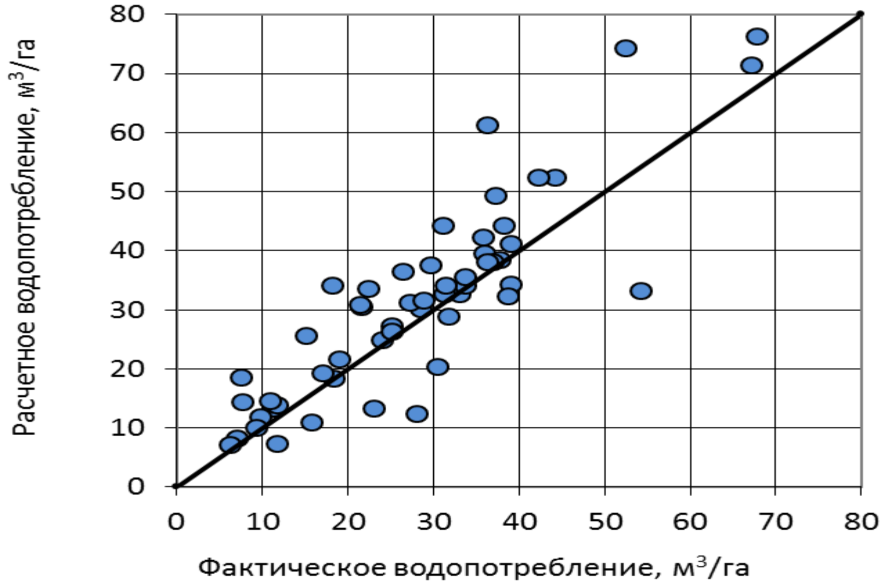
Fig. (5). Result of lucerne irrigation rationing modeling.

Validation of the PRNOSK program is carried out by comparison of results calculation of total water consumption by the A.M Alpatyev method and the program with data of field experiments (figure 6-7).



Расчетное водопотребление, м3/га	Estimated water consumption, m3/hectare
Фактическое водопотребление, м3/га	Actual water consumption, m3/hectare

Fig. (6). The chart of dispersion of the actual and calculated values of total water consumption by A. M. Alpatyev's method



Расчетное водопотребление, м3/га	Estimated water consumption, m3/hectare
Фактическое водопотребление, м3/га	Actual water consumption, m3/hectare

Fig. (7). The chart of dispersion of the actual and calculated values of total water consumption according to the PRNOSK program

The comparative statistical analysis of calculations results by different methods with actual data on water consumption showed the high level of correlation between them - the correlation coefficient for both methods made 0,88. The calculated value of Fischer criterion for sets of actual data on water consumption and certain according to the PRNOSK program makes 1,35, and for sets of actual data and certain by the A.M Alpatyev method - 1,46. At tabular value of F-criterion of Fischer 0,05 equal 1,44 as mean for significance value, results of calculation for the PRNOSK program have no statistically significant distinctions with data of a field experiment ($_{Ffakt}>_{Fteor}$), and results of calculation for the A.M. Alpatyev method have such distinctions ($_{Ffakt}>_{Fteor}$).

On higher reliability of the adapted model of total water consumption realized in the PRNOSK program also the calculated values of criterion of Nash-Sutcliffe allow to conclude: for "PRNOSK" it makes 72,8%, for the A.M. Alpatyev method - 71,7%.

4.DISCUSSION.

For adaptation of defining total water consumption model for lucerne and its cultivation in dry steppe Zavolzhye the coefficients used in model which for various periods of culture vegetation have the following values are experimentally established: "growth branching": An=0,54, β = 0,041, γ =1,54, $_{kb}$ = 0,31; "branching budding": An=0,81, β = 0,042, γ =1,58, $_{kb}$ =0,38; "budding blossoming": An=1,00, β = 0,044, γ =1,62, $_{kb}$ =0,45. Assessment of reliability of the adapted model and its computer realization - the PRNOSK program showed considerable narrowness of communication between the actual and certain data on the total water consumption of lucerne - the coefficient of correlation of r is equal to 0,88. Reliability of modeling results prove rather high value of Nash-Sutcliffe criterion - 72,8%, and also a calculated value of F-criterion - 1,35 which is less than tabular value for significance value 0,05 (1,44) that means lack of statistically significant distinctions between certain and actual data.

Comparison of calculation results for total water consumption by A. M. Alpatyev's method with actual data on water consumption showed the high level of correlation between them - r = 0,88. However, the calculated value of Fischer criterion for sets and certain by A. M. Alpatyev's method makes "actual data" 1,46 that, at tabular 1,44, means presence of statistically significant distinctions. Besides, values of Nash-Sutcliffe criterion for A. M. Alpatyev's method are lower, than for the PRNOSK program - 71,7%. On the basis of the carried-out calculations of lucerne cultivation on hay, it is possible to draw a conclusion that when rationing irrigation of lucerne on the basis of the offered model and the program of adaptive irrigation rationing efficiency of water resources use, receiving stable harvests of lucerne in dry steppe Zavolzhye, preservation of ameliorative condition of the irrigated lands, due to decrease in energy costs of receiving 1 t of production and increase in exchange energy by 1 m will increase with guarantee irrigating waters.

5.CONCLUSION.

Improvement of irrigation rationing quality gives the chance to lower excessive loads of the irrigated agriculture fields and to prevent deterioration in ameliorative condition of fields with use of more adaptive to ecological conditions methods of defining total water consumption and to increase efficiency of water resources use. Increase in adaptability of irrigation rationing to specific ecological conditions can be reached at fuller accounting of the factors influencing the water consumption of cultures, first of all dynamics of the water mode of an estimated ground layer, meteo-conditions, conditions of an active surface of the soil and biological features of culture (the relation to water) in the course of ontogenesis. Use of lucerne cultivation technology with use of the PRNOSK program will lead to preservation of water resources, increase in productivity of lucerne by 18,3%, decrease in expenses of irrigation water by 10% and power costs formation of 1 t. green material for 18,7%.

Further theoretical and pilot studies will be directed to adaptation of total water consumption model for other cultures of dry steppe Zavolzhye and in other soil and climatic zones.

REFERENCES

1. Abdrazakov F. K. Ways of developing land reclamation to the Volga region / F. K. Abdrazakov, V. A. Scherbakov, V. V. Sokolov//Scientific life. No. 2, 2014. page 84-99.
2. Abdrazakov F. K. The production organization for crop production with use of resource-saving technologies [An electronic resource] / F. K. Abdrazakov, L. M. Ignatyev//the Manual on discipline "The organization and management at the agrarian and industrial complex enterprises". Saratov, 2015.

3. Abdrazakov, F. K. Condition of ameliorative complex of the Saratov region and prospect of its development / F.K. Abdrazakov, V. S. Egorov//Agrarian scientific magazine. No. 3, 2003. page 74-79.
4. Alpatyev, A. M. Moisture circulations in the nature and their transformation / A. M. Alpatyev. - L., Gidrometeoizdat, 1969. - 323 pages (9)
5. Zatinatsky, S. V. Validation Model in technical rationing (on the example of resource-saving models of water consumption) / S. V. Zatinatsky, T. A. Pankova, E. Y. Shmagina, A. V. Kochetkov//"Science of science". - 2014. - No. 5. - [An electronic resource] the identification No. of article in magazine - 27TVN514. (72)
6. Zatinatsky, S. V. Resource-saving mathematical model of irrigation rationing / S. V. Zatinatsky, T. A. Pankova//"A scientific review". - 2013. - No. 11. - Page 10-13. (80)
7. Ivanov, N. N. About defining sizes of evaporability / N. N. Ivanov//Izv. GTO. 1954. - T.86. - No. 2. - Page 189 - 196. (86)
8. Konstantinov, A. R. Methods of evaporation calculation from agricultural fields / A. R. Konstantinov, N. I. Astakhova, A. A. Levenko - L.: Gidrometeoizdat, 1971. - 126 pages (102)
9. Koshkin, N. M. Automation of management of the crops watering mode taking into account weather conditions / N. M. Koshkin, S. V. Zatinatsky, T. A. Vasilchenko//"The agrarian scientific magazine". - 2010. - No. 7. - Page 58-61. (118)
10. Kravchuk, A. V. Improvement by the parameter of moistening for an agro-ecologic balanced modes for irrigation of forage crops in dry steppe Zavolzhye / A. V. Kravchuk//Abstract of the thesis for a scientific degree competition Doctor of Engineering / Volgograd: 2007. - 43 pages (125)
11. Pankova T. A. Management of the mode of crops watering /T. A. Pankova, A. A. Lemeshov//In collection: REGULARITIES AND TENDENCIES OF DEVELOPING SCIENCE IN MODERN SOCIETY the collection of articles of the international scientific and practical conference: in 3 parts. 2016. Page 9-11.
12. Pankova T. A. To a question of modeling for crop water consumption/T. A. Pankova, S. V. Zatinatsky, Z. Z. Dasayeva//In the collection: SCIENCE, EDUCATION AND INNOVATIONS Collection of articles of the International scientific and practical conference. Editor-in-chief: Sukiasyan Artur Albertovich. 2016. Page 49-52.
13. Pankova, T. A. K to a question of studying dynamics of moisture contents of the dark-chestnut soil of the Saratov Zavolzhye/T. A. Pankova//"Scientific life". - 2014. - No. 1. - Page 19-22. (175)
14. Pankova, T. A. Results of modeling of crop irrigation rationing for conditions of the Saratov Zavolzhye/T. A. Pankova//"A scientific review". - 2014. - No. 1. - Page 17-21. (181)
15. Pronko, N. A. Irrigation in the Volga region: not to repeat mistakes. / N. A. Pronko, V. V. Korsak, A.S. Falkovich//Melioration and water management - 2014, No. 4, S. 16-19. (197)
16. Certificate on the state registration of the computer program No. 2015661256 Program of calculation of crop irrigation rationing / Pankov T. A., Zatinatsky S. V.; owner FGBOU VPO "Saratov state agricultural university of N. I. Vavilov. - Federal State Budgetary Institution Federal Institute of Industrial Property, date of the state registration in the Register of the computer programs of 22.10.15, Moscow (the application No. 2015618158 of 08.09.2015). (210)
17. Scherbakov V. A. Land reclamation in the Volga region: the reasons of failures and prospect / V. A. Scherbakov, F. K. Abdrazakov//Melioration and water management - 2011, No. 4, S. 2-7.
18. Shumakov B. B. Melioration and water management. Tom. 6 Irrigation: The reference book / under. edition of B. B. Shumakov - M.: Agropromizdat, 1990. - 415 pages (144)

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