SUBSTANTIATION METHODOLOGY OF BIOCLIMATIC NORMS WATER CONSUMPTION OF CROPS IN KAZAKHSTAN

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ABSTRACT

The article analyzes methods for the determination of water consumption of crops. An algorithm for calculating sustainable water supply, which allows achieving high yielding capacity. On the basis of bioclimatic model of determining crops water consumption, the model of agriculturally used areas water consumption rationing is proposed, including the basic principles of land reclamation, improving of biological and preventing of geological circulation of water and chemicals. Developed algorithm for determining the rules of water consumption with the usage of meteorological data allows developing irrigation management software. The algorithm is very flexible, so it can be adapted to the specific features of the territory on which it is going to be used. This methodology can be applied in countries with arid climate. The proposed model would help to solve the problem of sustainable water consumption and irrigation of areas with inadequate water supply.

Key words: Arid climate, bioclimatic model, cultivated lands, evaporation, groundwater model, irrigation, underground water table, water supply.

INTRODUCTION

One of the features of agricultural industry in Central Asia is a critical shortage of water under the conditions of arid and semi-arid climate (Karthe *et al.*, 2015). This generate a need for finding ways of sustainable use of water and land resources at irrigated farming through a detailed \ study for the optimization of anthropogenically cultivated lands water consumption parameters and irrigation regimes of crops in modern conditions. Many countries with arid climate faced with the problem of insufficient irrigation of agriculturally used areas and uneven watering of cultivated plants (Scott *et al.,* 2008). Different variants of water usage, different irrigation regimes, and the usage of unconventional water resources have been proposed. Models and schemes of using sewage water for irrigation have been developed (Hamdy, 2000). A solution of the problem has been searched in predicting the weather and searching for the factors that affect it (Hansen, 2002), but the weather forecasting does not solve the irrigation problem, as it is just a prediction, not a change in weather (rain trigerring, reducing the temperature).

Water supply and temperature conditions are of great importance in order to ensure a high yield. Achieving of high yields is possible through the rational use and cultivation of the land and, that is also important, proper land irrigation (Chapagain and Yamaji, 2010). Favorable conditions for crops farming is being created by providing their biological potential on the background of rational use of natural resources. In this context, the development of biological needed and reasonable water consumption rationing in irrigated cultivation and optimal modes of irrigation of crops undoubtedly has practical and scientific value.

Methods based on the data about the total crops water consumption (evapotranspiration) have become widely used at performing water accounting in recent years. Globally, agriculture accounts for 80–90% of all freshwater used by humans, and most of that is in crop production. In many areas, this water consumption is unsustainable; water supplies are also underpressure from other users and are being affected by climate change. Much effort is being made to reduce water comsuption by crops and produce 'more crop per drop (Morison *et al.*, 2008).

About 15% of the areas used for growing plants are artificially irrigated. Irrigation therefore plays a large role in increasing arable production and cattle breeding efficiency, with irrigated farming expected to continue to develop intensively in the future, mainly in countries with extremely rapid population growth and .sufficient land and water resources.In addition to irrigation, there may also be the problem of supplying rural populations and livestock with high quality fresh water in many developing countries located in arid regions. However, costs for drinking water are insignificant compared with those of irrigation (Shiklomanov, 1998).

In regions such as North America, South Africa and the Middle East, where rainfall is inferior to the indicator of evaporation of water from the soil, as well as where water availability is less than 2,000 m^3 per person per year, there is a serious problem of water supply

(Bacon *et al.,* 2000). Irrigation of plowed field is important for the development of agriculture. Evaporation of water is one of the main characteristics of agriculturally used areas for which the various irrigation methods are being developed. This is why a lot of scientists are exploring the level of this rate and how it affects the yield. (Chave *et al.,* 2014). An example of irrational water consumption is a situation in Kansas (USA), where intensive irrigation led to the water depletion and a need to monitor the water consumption in this territory has appeared (Sophocleous and Perkins, 2000).

Incongruity of water consumption models and conditions places of their application leads to the loss of all the advantages of irrigation management using computers, reduction of economic efficiency, unproductive irrigation water use and development of environmentally unfriendly processes. In order to achieve an effective use of irrigated cultivated lands and a reduction of the risk of environmental degradation, it is necessary to develop an economically sound and sustainable technologies for crops water regime management as an integral part of farming systems, which are adapted to the agro-ecological conditions of reclamation of cultivated lands. The difficulty of solving this problem is caused by a large number of closely related processes, forming water regime and nutrient status of the soil (Ol'garenko, 2010). There is the SWAT model, which helps to estimate water consumption and soil salinity (Sadeghi *et al.,* 2013), but this model is a little outdated as it takes into account not all of the factors affecting water consumption. In most cases, it is applied to areas near rivers (Arnold *et al.,* 2012). Different models of water consumption due to groundwater have been developed (Ayvaz, 2009; De Graaf *et al.*, 2015). In this regard, there is a need for selection of alternatives, which would comply with the normalized water consumption regime of irrigation systems and provide a stable social and economic situation in the region and environmental sustainability in the development of anthropogenically cultivated lands (Zhang *et al.,* 2016). Irrigation techniques are being developed in regions with arid climate, but they are highly specialized for a particular region and are not adaptable for other territories. Our study offers a methodology that can be applied in different regions with arid climate with making inconspicuous adjustments for a specific territory.

METHODS

The basis of the methodological approach of rationing crops water consumption is a technique in which a bioclimatic model of water consumption evaluation has been previously used, followed by the establishment of irrigation norm by solving the equation of the water balance of irrigated field (Karpenko *et al.,* 2015). It helped us to improve irrigation scheduling and management system. We have analyzed and summarized data from various studies in this field and have created our own model based on the following indicators:

The value of the total water consumption is determined by the formula:

$$E_v = E \cdot k_¢ \cdot k_o , \qquad (1)$$

where $k_¢$ – biological coefficient; k_o – microclimate coefficient; E – evaporation (potential evapotranspiration).

The theoretical basis of computational methods for determining evaporation is the fact that at the optimum water supply of plants there is a close relationship between the evaporation by agricultural field and by atmospheric energy resources, which are estimated by such an integrated indicator as the evaporation (Ol’garenko, 2010).

Volatility is calculated by the formula (Zatinackij *et al.,* 2014):

$$E = K_t \cdot d \cdot f(u) , \qquad (2)$$

where K_t – energy evaporation factor; d - humidity deficit, mb; $f(u)$ - function characterizing the effect of wind.

Evaporation parameters K_t and $f(u)$ are determined by the relationship:

$$K_t = \frac{0{,}0061(25+t)^2}{l_a} , \qquad (3)$$

where t - air temperature, °C; l_a - saturated vapor pressure, mb.

$$f(u) = 0{,}64 + 0{,}12u_2 , \qquad (4)$$

where u_2 - wind speed at a height of 2 m over the ground surface, m/s.

In order to determine the crops biological factor ($K_¢$) depending on the temperature curve ($\overline{T}i = \sum t / 1000$), regression function is offered (Karpenko *et al.*, 2015):

$$K_¢ = A \cdot \overline{T}^3 + B \cdot \overline{T}^2 + C \cdot \overline{T} + D , \qquad (5)$$

where $K_¢$ - conditional average value of the biological factor; $\overline{T}_i = \sum t / 1000$ - dimensionless temperature curve, characterizing the amount of air temperature during the growing season in the cumulative sum; *A, B, C, D* - parameters of regression function.

These parameters are the basis of computation for our model. They were used for analysis and development of an algorithm given in the results of our research.

RESULTS

Under the irrigation management, optimal planning of control actions should lie in such a selection of output values of the system, which is could ensure environmental and economic sustainability of irrigated cultivated lands. In order to solve the problem of irrigation optimizing in conditions of insufficient use of natural moisture, deficits in water consumption are used, which would be determined based on the water balance of irrigated cultivated lands:

$$\Delta E_{vi} = E_v - (O_c + V_a + G), \quad (6)$$

where E_v - total water consumption (evapotranspiration) of a growing in optimal water supply conditions for plants; O_c - atmospheric precipitation; W_a - net amount of water in given layer of soil; G - capillary moisture flow from the groundwater at their close occurrence at the surface. Net amount of water:

$$W_a = W_{mr} \cdot « \cdot (1 - \ _o) \cdot h_k, \quad (7)$$

where W_{mr} - moisture reserves in one meter soil layer, mm; $_o$ - acceptable level of soil drying out before watering; « - coefficient indicating the degree of actual soil moisture saturation before vegetation; h_k - given soil layer that varies during the growing season, cm.

Participation of groundwater in plants water supply is only possible in case of their close occurrence, i.e. the inflow of groundwater (G) is determined by the formula:

$$G = E_v \cdot g_r, \quad (8)$$

where g_r - coefficient of additional capillary supply, the proportion of E_v (total water consumption), which depends on the depth of groundwater, soil texture and depth of plants network of roots.

Irrigation norm is equal to amount of deficits of water consumption for every ten days in growing period of irrigated crops:

$$O_p = \sum_{i=1}^{n} \Delta E_{vi}, \quad (9)$$

where O_p - net irrigation norm; ΔE_{vi} - deficits of water consumption during the time interval.

Depending on the plant development and soil-reclamation features, it is offered to make water balance schedules for each field, which would determine the norms of water supply for the development of plants and acceptable level of moisture deficit in the soil (Karpenko *et al.*, 2015).

In order to solve the problem, it is necessary to search out water consumption, irrigation norms and the average date for the irrigation, providing optimal conditions for the growth and development of plants, i.e., apply the formula:

$$W_{sc} \geq W_i \geq \sim_{dl} \cdot W_{sc}, \quad (10)$$

where W_{sc} - smallest water capacity in the active layer of soil; W_i - critical water capacity corresponding to the lower level of acceptable soil moisture; $\sim_{dl}$ - drying out limits in fractions of a unit of the lowest soil moisture.

The algorithm was developed in order to solve the problem, and it requires the definition of the following indicators:

1. Amount of air temperatures (TM) for decade in the growing season:

$$TM(m_i) = t_i \cdot m_i, \ m_i = 10 \wedge 11, \quad (11)$$

where t_i - ten-day average air temperature,

2. Integral amount of air temperatures (CTM) (m_i) for the decade

$$CTM(m_i) = CTM(m_i)_{i-1} + TM(m_i). \quad (12)$$

3. The duration of growing season on a cumulative sum:

$$T(m_i) = T(m_i)_{i-1} + m_i, \ m_i = 10 \wedge 11. \quad (13)$$

4. The biological factor, reflecting the peculiarities of the plant development:

$$K_{¢_i} = A \cdot \left[\frac{CTM(m_i)}{1000}\right]^3 + B \cdot \left[\frac{CTM(m_i)}{1000}\right]^2 + C \cdot \left[\frac{CTM(m_i)}{1000}\right] + D, \quad (14)$$

where A, B, C, D –parameters of the equation.

5. Ten-day evaporation is calculated according to the formula (Ivanov, 1954):

$$E_{oi} = 0.0006 \cdot (25 + t)^2 \cdot (100 - a) \cdot m_i, m_i = 10 \wedge 11, \quad (15)$$

where a - average relative air humidity per decade.

6. Photosynthetically active radiation (PAR) during the growing period determined by the following relationship:

$$Q_b = 13.93 + 0.0079 \cdot CTM(m_i). \quad (16)$$

7. The highest potential value of yield is achievable depending on following:

$$PY = Q_b \cdot K_Q / C \cdot \circ_n , \quad (17)$$

where K_Q - coefficient of solar energy usage; C - calorific value of the yield unit, kcal / kg, $\overset{\circ}{}_n$ - coefficient of transition from yield crop product to yield of the whole organic mass.

8. The photosynthetic coefficient, which characterizes the change in the maximum potential yield with PAR derated from the long-term average annual values, is measured:

$$f_Q = \frac{(Q_b - Q_{\min})}{[0.5(Q_{\max} + Q_{\min}) - Q_{\min}]} , \quad (18)$$

where $Q_{\min}$ - minimum value of PAR required for the maturing of the crop, kcal/cm^2; $Q_{\max}$ - maximum value of PAR required for the maturing of the crop, kcal/cm^2.

9. Coefficient characterizing the temperature security of the natural environment:

$$K_t = \begin{cases} 1, \text{ if } K_t = \dfrac{CTM(m_i) - \sum t_{\min}}{[0.5(\sum t_{\max} + \sum t_{\min}) - \sum t_{\min}]} \geq 1.0 \\ K_t' \text{ if } K_t' < 1.0 \end{cases} . \quad (19)$$

Planned yield in particular years or an average of over long-time period with optimal nutrition and water regime can be determined:

$$Y_{\max} = PY \cdot K_t \cdot f_Q . \quad (20)$$

If $f_Q \geq 1.0$, calculation shall assume $f_Q = 1.0$, as the PAR does not limit the formation of the maximum possible yield.

10. In order to determine the total water consumption by crops with a given productivity equation we used:

$$E_i = K_o \cdot K_{\text{¢}} \cdot K_{\bar{Y}} \cdot E_o , \quad (21)$$

where K_o - microclimate coefficient; $K_{\bar{Y}}$ - coefficient of highly effective productivity of the plant.

Changing of crop under the influence of environmental factors dY / dX in proportion to the degree of optimality X_{opt} and the deviation from the optimum value (X_{opt}– X_i) , i.e., according to Mitscherlich's law:

$$dY / dX = C_i (X_{opt} - X_i) , \quad (22)$$

where C_i - invariable for this factor; X_{opt} - optimal value of the factor.

To evaluate the effect of water regime on the value of the harvest will solve the equation $dY / dX = C_i (X_{opt} - X_i)$ with the following delimitations:

$$X_i = W_i = W_{mc}; \qquad Y_i = 0;$$
$$X_i = W_i = W_{opt}; \qquad Y_i = Y_{opt} = Y_{\max}. \quad (23)$$

After we got:

$$Y_i = Y_{\max} \{1 - [1 - (W_i - W_{mc}) / (W_{opt} - W_{mc})]^2\} , \quad (24)$$

where $Y_{\max}$ - maximum yield at current values of factors; W_i - the actual values of moisture content during the growing season; W_{mc} - minimum moisture content, limiting the life of the plant (humidity, wilt). Supposing that $(W_i - W_{mc}) / (W_{opt} - W_{mc}) = E_i / E_o$, then the dependence of the harvest from the total water consumption is:

$$Y_i = Y_{\max} [1 - (1 - E_i / E_o)^2] . \quad (25)$$

11. Integral total water consumption (CE_i) is calculated according to the equation:

$$CE_i = CE_{i-1} + E_i . \quad (26)$$

12. The power of crops network of roots is defined by the relationship [4]:

$$H(T)_i = \text{¥} \cdot Z_{ek} \{1 - \exp[-(2 \cdot T(m_i) / T_k)^2]\} , \quad (27)$$

where $H(T)_i$ - power of network of roots, 0,40 m; ¥ - scaling coefficient that is bigger than 1, providing $T(m_i) = T_k$ value $Z_e = Z_{ek}$.

As a result of the analysis and statistical processing of experimental data of crops irrigation in Kazakhstan, Kyrgyzstan and Uzbekistan, the values ¥ , Z_{ek} и T_k were obtained.

Then, the permissible limits of active soil drying out in a fraction of the water capacity:

$$_0 = \{1 - [E_i / H(T)_i \cdot d]\} \cdot \; _{wc} . \quad (28)$$

In order to calculate the soil moisture, corresponding optimal moisture diapason, it is advisable to use the analytical calculation:

$$W_{OMD} = (\sim - pF_{OMD}) / \text{¢} , \quad (29)$$

where W_{OMD} - soil moisture, %; $\sim$, ¢ - coefficients; pF_{OMD} - logarithm of pressure:

$$\sim = \frac{pF_1 (W_2 - W_1) - W_1 (pF_2 - pF_1)}{(W_2 - W_1)} ,$$
$$\text{¢} = \frac{W_1 (pF_2 - pF_1) - pF_1 (W_2 - W_1)}{pF_2 - pF_1} , \quad 30)$$

here pF_1, pF_2, W_1, W_2 - limit values of the interval, including pF_{OMD}.

Osmotic pressure of dilute solutions obeys the ideal gas law; the status of these solutions is expressed by Van 't Hoff equation:

$$\ddot{} = C \cdot R \cdot T \ , \qquad (31)$$

where - osmotic pressure, atm.; C - molar concentration of solute; R - universal constant, independent of the type of solvent and solute and numerically equal to the gas constant (8.3144598 J mol^{-1} K^{-1}); T - absolute temperature.

Matric potential at maximum hygroscopic moisture capacity, obtained by the sorption equilibrium with a saturated solution of potassium sulfate, is calculated by the formula:

$$\ddot{}_W = \frac{R \cdot T}{\Pi} \ln \frac{P}{P_o} = 2723 \text{ J/kg} \ . \qquad (32)$$

Then $\ddot{} = \ddot{}_W \cdot {}^{\circ}_W = 2723090 \text{ Pa}$;

$\ddot{}_W = \ddot{} / g = 278{,}08 \text{ mm } H_2O;$

where $R = 8{,}3143$ - annual constant, J/kmol; $T = 293{,}15^0$ - temperature; $P = 0{,}01805 \text{ kg/mol}$; $P/P_0 = 0{,}98$ - relative humidity over a saturated solution of potassium sulphate; ${}^{\circ}_W = 998{,}2$ - density of water at 20 ^{0}C, kg/m^3; $g = 9{,}81$ - gravity acceleration, m/s^2.

The osmotic potential of the soil solution can be calculated as follows:

$$\ddot{}(W,C) = ¥ \cdot EC^{¢} = 0{,}321 \cdot EC^{1.06},$$

$$EC = \sim + \quad \cdot S = 0.8 + 0.109 \cdot S$$

$$S = C_i (W_i / W_{sc}), \ , \qquad (33)$$

where $\ddot{}(W,C)$ - the dependence of the osmotic potential from the humidity and salinity of soil moisture; EC - the electrical conductivity of the soil solution, mmo / cm; $\sim$, , ¥, ¢ - empirical constants.

13. Calculation of irrigation norm carried out according to the formula:

$$m = [100 \cdot H(T)_i \cdot d_n (\ _{mr} - W_{OMD})] / d_{H_2O} \ , \qquad (34)$$

where m - irrigation norm, m^3/ha; $H(T)_i$ - thickness of moistened soil, m; d_n - soil density (bulk density) g / cm^3; d_{H_2O} - water density (1,0 g/cm^3).

In order to perform calculations on the moisture regime, it is necessary to know the parameters of moisture transmission, i.e., dependence of soil water potential from humidity $\ddot{} = f(W)$:

$$\ddot{}(W) = \quad \{\ln[(W - MG)/(P - MG)]^{1/C}\} \ . \qquad (35)$$

Thus, the basic hydrophysical characteristics of soil are reliable criterion of plants water supply level. It can serve as a necessary and sufficient parameter for finding lower bounds of available moisture range, the optimal range of available moisture and optimal range of moisture diapason and, ultimately, be the controlling element in creating high-performance irrigation systems.

The pre-irrigation moisture of the given soil layer is determined:

$$_{pi} = \max[\ _o, W_{OMD}] \ . \qquad (36)$$

14. Additional deposits of moisture in the soil, used by plants with deepening the root layer of soil was calculated by the formula:

$$\Delta WD_i = \{100 \cdot d_n [H(T)_{i+1} - H(T)_i](\ _{lc} - \ _{pi})\} / d_{H_2O} \ , \qquad (37)$$

where d_n - soil bulk density, g / cm^3; $_{lc}$ - the lowest moisture content, % of oven-dry soil weight.

Deficiency of active moisture deposit in the root layer of soil was calculated:

$$\Delta WA_i = \{100 \cdot d_n \cdot H(T)_i (\ _{lc} - \ _{pi})\} / d_{H_2O} \ . \qquad (38)$$

Formula S.F. Aver'janov was used in the calculation of evaporation of groundwater (Aver'janov and Osipov, 1990):

$$E = E_o [1 - (H_o / HK)^2] \ , \qquad (39)$$

where E_o - depth of groundwater in irrigated areas, m; HK - critical depth of groundwater, when $E = 0$.

Useful stockpile of moisture at the end of the decade will be:

$$\Delta WI'_i = \Delta WI_i + \Delta WA_{i-1} + 10 \cdot \sim \cdot P + \Delta WA_i - E_i \ , \qquad (40)$$

where $\sim$ - coefficient of atmospheric precipitation usage, equal to 0,5 – 1,0; $\Delta WI_i, \Delta WA_{i-1}$ - useful water stockpiles at the end of this and the previous decade, m3 / ha.

15. Water balance deficit will be equal to:

$$DE_i = E_i - (\Delta WD_i + 10 \cdot \sim \cdot P + E) + CB_i, \qquad (41)$$

while if $DE_{i-1} \neq 0$, then:

$$DE_i = E_i - (\Delta WD_i + 10 \cdot \sim \cdot P + E) + CB_i + DE_{i-1} \ . \qquad (42)$$

16. The algebraic sum of deficits of the water balance with cumulative sum we will get from the expression:

$$CDE_i = CDE_{i-1} + DE_i \quad (43)$$

Let us define the need for watering and irrigation norm:

$$\text{if} \quad \Delta WI_i - DE_i = 0, \quad \text{then} \quad \Delta MI_{\max_i} = \Delta WA_{\max},$$
$$\text{if} \quad \Delta WI_i - DE_i \geq 0, \quad \text{then} \quad \Delta MI_{\max_i} = 0. \quad (44)$$

17. The average date of the irrigation period CP_i is determined by the ratio between the unused part of water stockpiles at the beginning of the decade ΔWI_{i-1} and daily average for decade *i* deficit of water balance , if $\Delta MI_i = \Delta WA_{\max}$, then:

$$CP_i = 10 \cdot (DI_{i-1} - 1) + (\Delta WA_{\max} \cdot m_i / DE_i) + 1, \quad (45)$$

if $\Delta MI_{i-1} = 0$, then $CP_i = 0$.

18. Ordinate of irrigating modulus for the rotation of the array based on the share of crop area in the crop rotation is determined:

$$q = (\sim_1 DE_{1i} + \sim_2 DE_{2i} + ... + \sim_n DE_{ni}) / (86.4 \cdot m_i). \quad (46)$$

19. When the calculations for a number of years are made, these data are arranged in ascending order. Security is calculated for each year (as a percentage):

$$oq_i = [(m_o - 0.3)/(n - 0.4)] \cdot 100, \quad (47)$$

where n - numerical order; m_o - a number of years.

Comparing with analogs, a distinctive feature of the proposed algorithm for determination the norm of crops water consumption is the consideration of not only hydrophysical properties of the soil and weather conditions of the region, but also hydrophysical soil characteristics and flexibility of the developed methodological approach.

The proposed method allows us to calculate all the necessary data required for rational water consumption and ensure an equal water supply.

DISCUSSION

In the countries of Asia, Africa, Central and South America, where there is a great variety of climatic conditions, crop composition and watering techniques, the values for specific water withdrawal range from 5000-6000m^3/ha to 15,000 to 17,000 m^3/ha and in individual regions of Africa, 20,000-25,000 m3/ha (Green *et al.*, 2015). Certain changes in the irrigation system, which led to a decrease of evaporation of water from the soil, were performed in North America (Nielsen *et al.*, 2005). It is very urgent task of creating such irrigation systems, which would allow maintaining the natural structure of the groundwater balance. Solution to this problem requires the development of irrigation technology, which virtually eliminates water loss through filtration and surface fault for the conservation of soil automorphous regime, taking into account the cyclical nature of natural processes (Ol'garenko, 2005).

Previous studies in this area also offered models based on calculations of air temperature, humidity, rainfall, but these models were module systems that constantly monitored the status of these indicators. They allowed forecasting the amount of water consumption and growth of crops up to a month (Pokhrel *et al.*, 2012). Our model takes into account the development of the plants and gives an opportunity to determine the potential value of the yield, to estimate the impact of water regime on the future harvest. Using this model, we can predict the expected value of the yield. Other researchers had created a model of the water supply via groundwater (Cibin *et al.*, 2014), which can be used together with our model in those areas where large deposits of groundwater occur, but the climate is arid.

Integrated model that takes into account the annual variability of water resources was proposed in 2008 (Hanasaki *et al.*, 2008), while our algorithm takes into account these changes in the course of the growing season, which is more important for the agricultural industry. Our study offers an alternative method of calculating rational water demand lands, which can be applied to agriculturally used areas that are in similar climatological conditions. This model might be applied to countries with arid climate and lack of water supply, but it can also be applied to areas with mild climate and water supply taking into account certain differences in amount of evaporated water, amount of groundwater and their distance to the earth's surface.

Water consumption methods may include different level of computer programming: linear (Hallaji and Yazıcıgil, 1996).), nonlinear (McKinney and Lin, 1992), dynamic (Culver and Shoemaker, 1992). Our algorithms is applicable for computer release and it does not contradict heuristic harmony search (Ayvaz, 2009).

Conclusions: Thus, the principle of energy balance of heat and moisture was taken as a basis of developed methodology. It also takes into account the biological characteristics of plants (growing period, the amount of water required for normal growth). The proposed algorithm of optimization of crops water consumption bioclimatic norms can be used in order to create an information system of irrigation management.

Proper usage of this system will have a positive effect on water supply of grown crops, and, consequently, on the quality and quantity of the yield. This technique will improve the productivity of agriculturally used areas and rationalize their water consumption, avoiding the excessive consumption of water resources, which already are in short supply in these areas. The purpose of the algorithm is to develop efficient technologies that would ensure efficient use of water resources with the maximum return in their natural reservoirs (lakes, rivers, open water and groundwater). If the water used in irrigation cannot be returned to nature, it should be cleaned and used in the future as the process water.

The results of this study are applicable not only in Kazakhstan but also in other countries where there are areas with arid or semi-arid climate. The results of this study can be used for arranging lands for the cultivation of plants with a great need for water supply. Smart usage of irrigation as one of the types of water consumption might prevent irrigative corrosion, resalinization and terrain subsidence. It push the boundaries for agricultural industry, and can serve as a new source of profit for the state's economy.

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