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APPROACHES TO JUSTIFICATION OF AGRICULTURAL LAND RECLAMATION IN THE SOUTH OF UZBEKISTAN UNDER POSSIBLE CHANGES IN CLIMATIC INDICATORS

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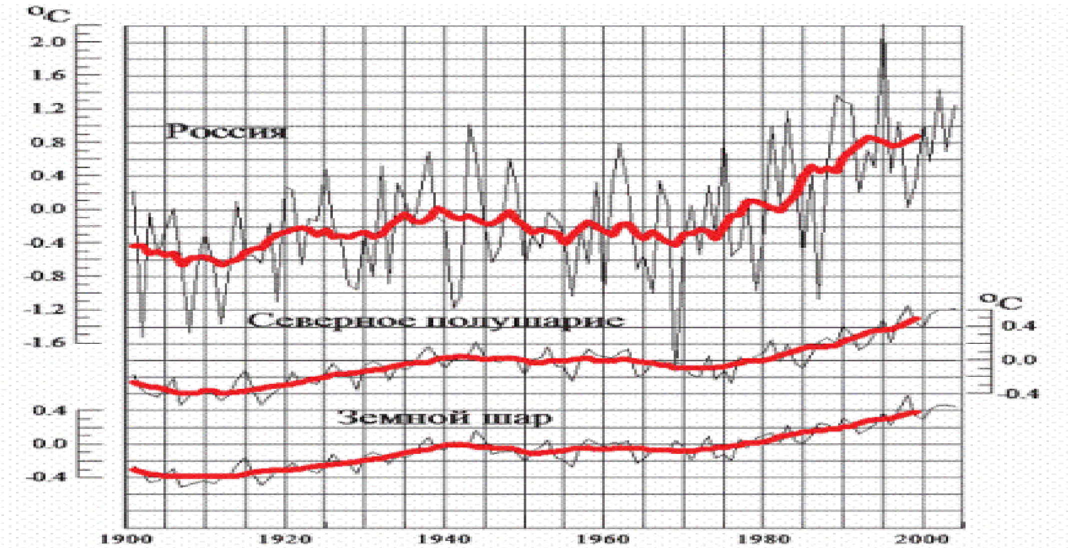
Abstract
The development and location of agricultural land reclamation is directly related to climatic changes. Today, the problem of adaptation of agricultural production, as the most sensitive and vulnerable to climatic factors, comes to the forefront.

Introduction

According to observations of Russian meteorological stations, the average annual air temperature in southern Uzbekistan has increased by 1 ºC over the last 100 years (which is much higher than the world average), including 0.4 ºC in the last decade of the 20th century alone. According to the forecasts of the Main Geophysical Observatory named after A.I. Voyeykov, in accordance with the calculations of future climate change, by the end of the 21st century in the Republic, a temperature increases in the south of the country by another 0.6°C should be expected [1...5]. Under the aggressive anthropogenic scenario (RCP 8.5), the average annual temperature in the whole territory of our country will increase by 5-8°C. According to Uzhydromet forecasts, by the middle of this century the Republic will warm up by almost 2 degrees Celsius if the temperature growth rate remains at the same level.



In most of the northern part of the territory of the Republic, an increase in the number of days with abnormally high precipitation (> 10 mm) is observed in winter, and in summer - on the contrary, their decrease [1...5].

The growth of average annual air temperature occurs in all territories of the Republic, but due to the large length of the territory and the diversity of its natural conditions, climatic changes manifest themselves unevenly in different regions and seasons of the year.

The most accurate forecasts of climatic changes are obtained with the help of simulation models 'weather-harvest', the best models of global climatic changes under a set of climatic scenarios with subsequent generalisation of the results.

Under warming under this scenario, both winter and summer air temperatures are expected to increase.

Table 1. Changes in climatic indicators under different scenarios

A model, a scenario	HadCM3-A1P1 (arid)	MPK (GGO) (humid)
Air temperature, ºC		
July	5,1	1,3
January	5,2	4,8
Sum of temperatures above 10ºC, ºC	1094	266
Growing season	34	13

For agriculture, the following are expected: increase in the duration of the growing season by 26 days, increase in the sum of active temperatures, increase in precipitation by 26 mm and evapotranspiration by 141 mm.

The table also characterises probabilistic climate changes under the arid scenario. The increase in air temperature in January under the compared scenarios differs by 0.40C, while the expected increase in July temperature under the arid scenario is 5.1, while under the humid scenario it is only 1.30C. Obviously, the humid scenario, which implies a significant decrease in the degree of climate continentality, is much more favourable for agriculture in the Republic of Uzbekistan.

Increasing frequency of extreme weather events, changes in precipitation and temperature indicators will lead to a decrease in crop yields and the role of the agricultural sector in GDP. Water reclamation plays a significant role in ensuring adaptation of agriculture under changes in water availability of the territory.

We have developed a methodology to account for the impact of possible climate change on water availability in the territory. For this purpose, models of agroclimatic zoning of productivity, crop yields depending on the coefficients of heat and moisture availability, as well as models of soil water regime are used. This makes it possible to forecast the probability of necessity of water reclamation development depending on changes in water availability of the territory under climatic changes, possible ecological consequences under changes in the structure and volume of reclamation measures and to propose a set of measures for water resources protection. Fig. 2 shows the block scheme of applied models, which allows to perform such an assessment.

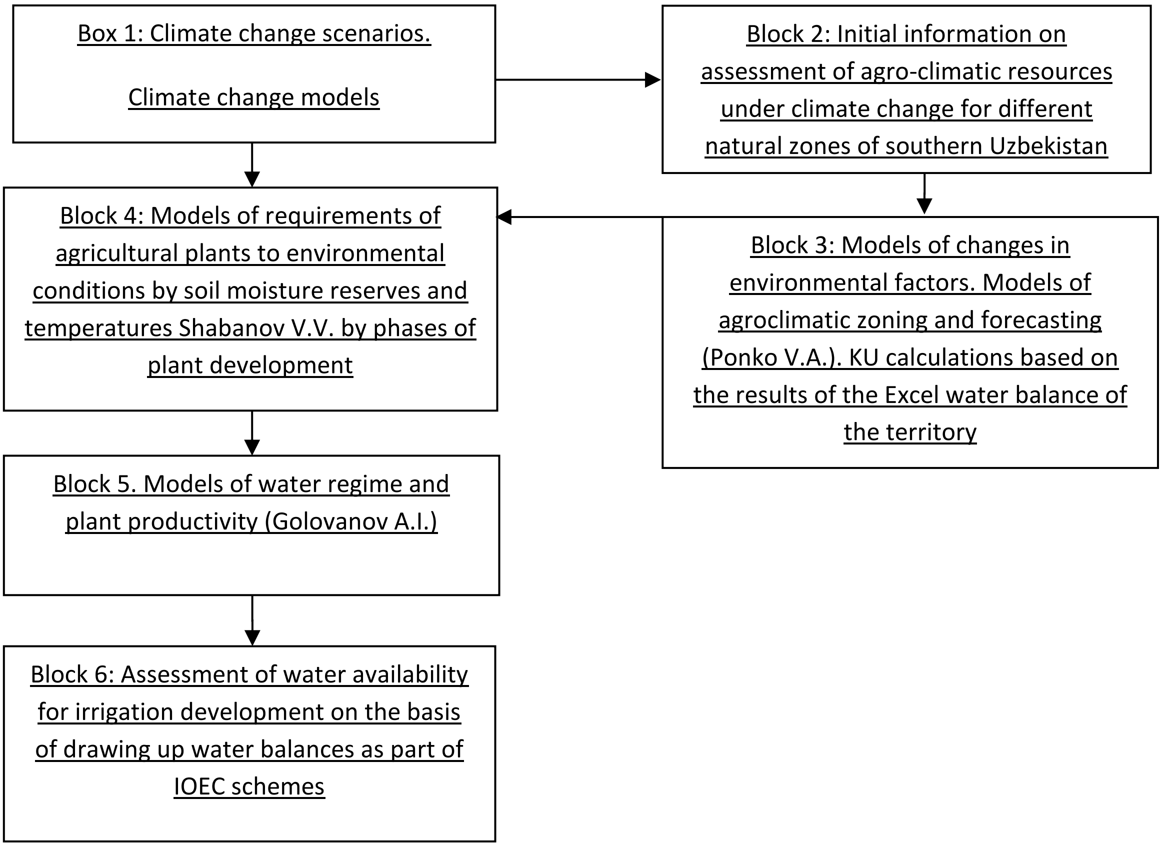


Figure 2. Block diagram of applied models for taking into account climatic factors when assessing the necessity of reclamation development land reclamation

At the first stage, the change in crop yields depending on the moisture availability of plants by phases of their development is calculated using the model of Shabanov V.V. (2.1) [1]:

$$U_W = U_{\max} \sum_{i=1}^{n} \alpha_i k_{W_i} \,, \qquad (1)$$

where: U_W - yield at the given variant of moisture reserves; U_{max} - maximum possible yield at optimal moisture dynamics for the plant; - contribution of the i-th decade to productivity formation depending on the phase of plant development; n - number of decades in the vegetation period; - coefficient determining productivity decrease due to deviation of soil moisture from the optimal one in the given decade (2).

$$k_{W_i} = \left(\frac{\theta_i}{\theta_{opt_i}}\right)^{\gamma_i \theta_{opt_i}} \left(\frac{1-\theta_i}{1-\theta_{opt_i}}\right)^{\gamma_i \left(1-\theta_{opt_i}\right)}$$

(2)

где $\theta_i = \frac{W_i - W_Z}{m - W_Z}; \theta_{opt_i} = \frac{W_{opt_i} - W_Z}{m - W_Z}$

W_i - average for the i-th decade moisture content of the root-inhabited soil layer; - W_{opt_i} optimum moisture content; m - moisture content corresponding to full soil moisture capacity; W_Z - wilting moisture content; γ - coefficient taking into account plant reaction to deviation of moisture content from optimum.

The need for different types of water reclamation is justified using the bioclimatic method by comparing the requirements of agricultural plants to soil moisture reserves, as well as to their distribution by phases of plant development in years of estimated availability for different scenarios of climatic changes.

At the second stage, the wetting coefficient (Cu) is estimated, which is one of the main criteria affecting the productivity of agricultural land. Taking into account this coefficient, justification of land reclamation areas is carried out taking into account climatic changes. Humidification coefficient is a ratio between the amount of precipitation falling in a given area, evapotranspiration or air temperature determining evapotranspiration according to the formula (2.3) [1]:

$$Ky = O / E\ To, \quad (3)$$

where O is the sum of precipitation of the growing season in mm; To is the sum of average daily positive temperatures (above 0^o C); E is the empirical coefficient 0.177, by means of which the value of heat energy is converted into evapotranspiration (degrees of heat in mm of transpiration)..

Estimated wetting coefficients are calculated relative to the climatic optimum corresponding to the maximum productivity of cereal-grass biocenosis on chernozem, or relative optimum in farming ($Ku_{zem\ opt}$) corresponding to the maximum productivity of agrocenosis.

At the next stage the productivity of zonal soils and crop yields are calculated, expressed in grain equivalent (t.grain unit/ha), which is calculated by formulas (2.4) [1...5]:

$$V = K_t \cdot K_{фар}\left(e^{\pi \cdot k_o \cdot k_y} - 1\right), \text{если } k_y < 1, \quad (4)$$

$$V = K_t \cdot K_{фар}\left(e^{\pi \cdot k_o \cdot (1/k_y)} - 1\right), \text{если } k_y > 1$$

where Kt is the heat availability coefficient weighted by the Kfar coefficient; Ky is the wetting coefficient relative to the natural optimum corresponding to the maximum natural productivity of soils at climatic value Ku=1.0; Constants e = 2.718..., π = 3.14...; Development coefficient ko equal to 1.0507 or $(1.0166)^3$. Heat availability coefficient is calculated as the ratio of the sum of average daily positive (active) temperatures of the growing season to the maximum climatic sum of temperatures on Earth (10946 0^0 C). K_{FAR} - coefficient of light energy or photosynthetically active radiation (PAR) utilisation by plants. K_{FAR} in the base variant is taken as 1.0, which corresponds to the coefficient of efficiency of PAR approximately 2.5%.

As can be seen from the table, under the arid scenario of climatic changes, the moisture coefficient decreases by 13-30%, while the productivity of cereals decreases by 30% compared to the current level.

Crop productivity calculations were made for two scenarios of climatic changes by phases of plant development. The range of soil moisture reserves, at which the productivity of plants will be optimal, has been determined.

To assess the need for water reclamation, the values of soil moisture reserves corresponding to optimal productivity are plotted on the integral curves of normal distribution of soil moisture reserves for both actual and forecast scenarios of climatic changes. The results obtained on the need in land reclamation for arid climate change scenario are given in Table 3.

Table 2. Estimated forecast values of the moisture content coefficient for the south of Uzbekistan

Calculation method	Excluding climate change		Arid climate change scenario
	Methodology of V.A. Ponko.		
Koo	1,33		1,15
V, t.s.e. /ha	2,38		1,34
	Methodology of Ivanov A.L.		
Koo	1,3		0,91
V, t.s.e. /ha	2,1		1,31
Required humidification coefficient		1,4-1,5	
Required production potential t.s.e.m. /ha		6,2	
Actual grain yields for the period from 2006 to 2012.		1,9	

Note - *V* - production potential, Ku - wetting coefficient, t.z.u/ha (tonnes of grain units per hectare).

According to the results of the made forecast assessments under arid scenario of climatic changes for the south of Uzbekistan, the probability of optimal conditions for grain growing decreases on average by 23 % and, as a result, the probability of necessity of irrigation reclamation increases by 51 %. At the same time, the need for drainage reclamation will decrease by 25%. Cultivation of grain crops without irrigation reclamation in case of climate change under arid scenario can lead to 32-50% loss of productivity.

At the minimum level of optimal productive moisture reserves for spring wheat cultivation, the probability of irrigation reclamation is 0.16, and at the maximum values of the optimal range of more than 89mm, the probability of drainage reclamation of sod-podzolic soils is 0.23 or 23% (Fig. 3).

Table 3. Probability of optimal conditions and necessity of land reclamation development without taking into account (P1) and with taking into account (P2) climatic changes for cereals under arid scenario

Phases of plant growth and development		1	2	3	P%
Optimal conditions	P^1_{opt}	22	57	32	decrease of 23%
	P^2_{opt}	23	7	0	
Dehumidification	P^1	78	28	0	decrease of 25%
	P^2	0	18	18	
Irrigation	P^1	0	15	68	51% increase
	P^2	77	75	82	

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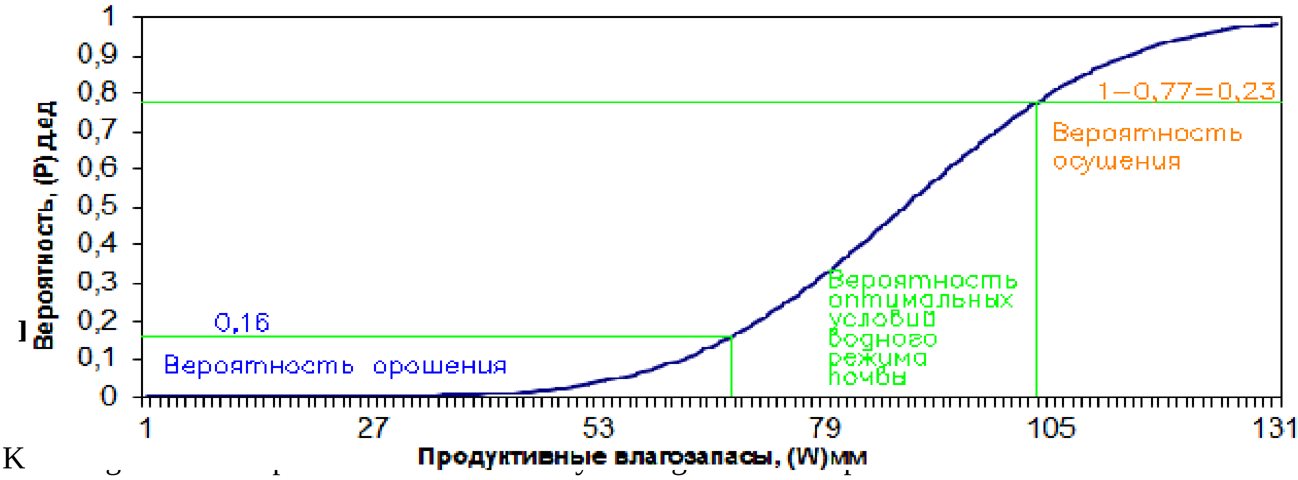
In case of development of climatic changes in the south of Uzbekistan under arid scenario it will be necessary to increase the area of irrigated lands up to 580 thousand hectares, which is 22% more than the current area of 477.5 thousand hectares.



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climatic changes and the degree of grain crops productivity reduction under changing of territory wetting coefficient, the required wetting levels for different zonal soils of the Republic of Uzbekistan were justified (Fig. 4). Productive potential of grain crops at the required level of moistening of zonal-provincial soils, which can be achieved only with the development of land reclamation (under arid scenario of climatic changes - irrigation), is shown in Figure 5.

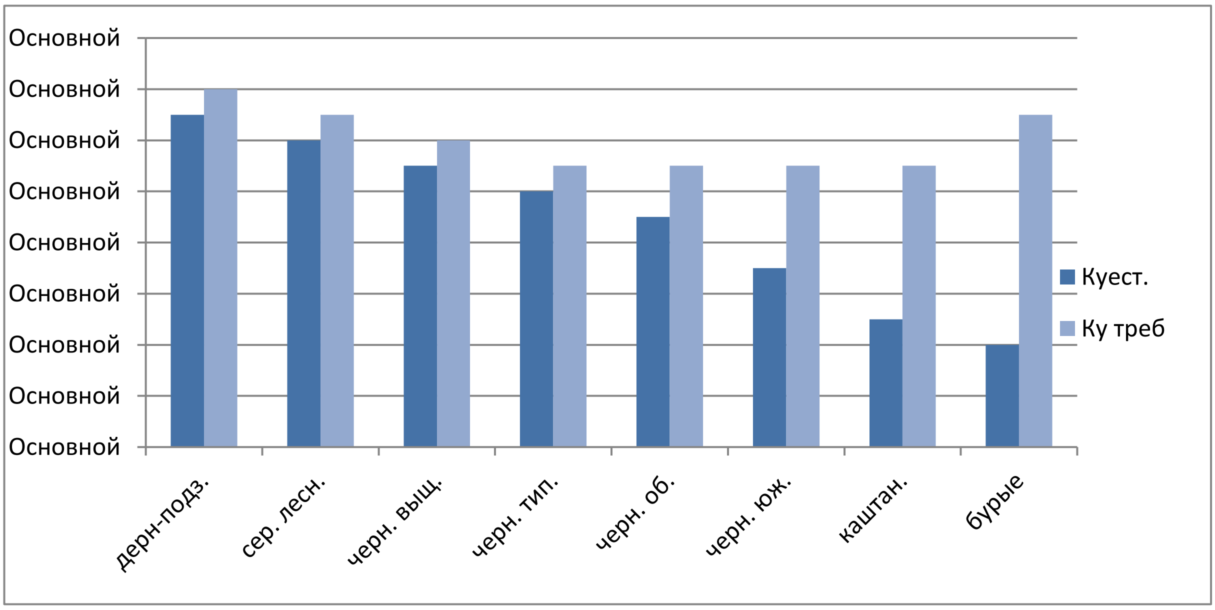

Fig. 4 - Required values of moistening coefficient for zonal soils of the Republic of Uzbekistan

(Note: Cuest. - wetting coefficient in natural conditions, KUrequire - required wetting coefficient)

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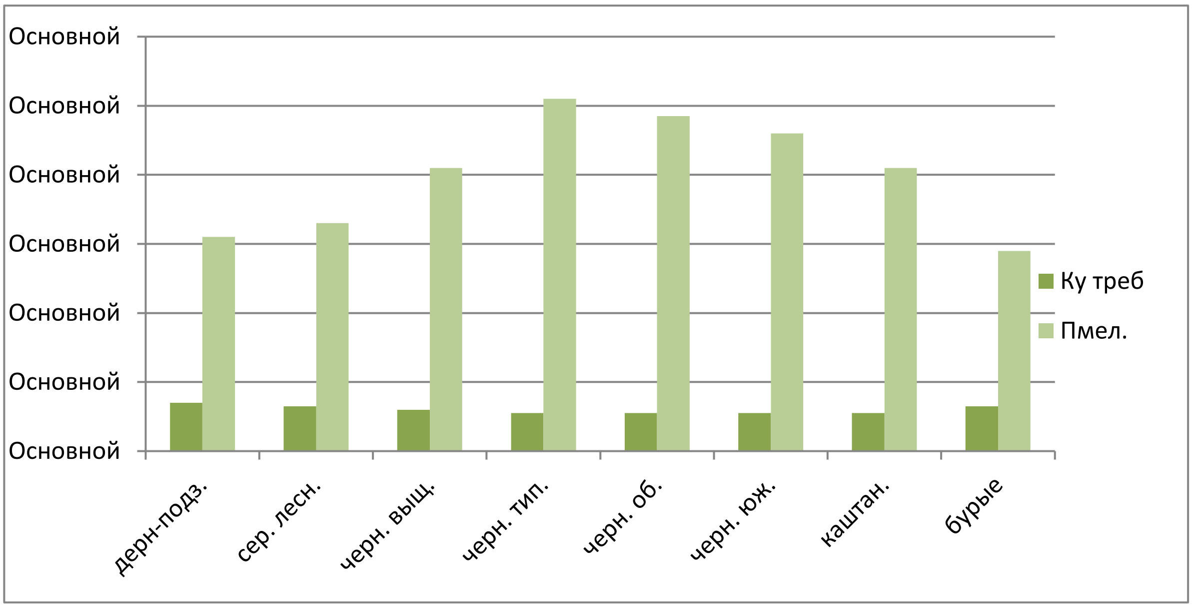

Fig. 5 - Productive potential (Pmel.) and required values of wetting coefficients for growing grain crops for zonal soils of the Republic of Uzbekistan under reclamation development (under arid scenario of climatic changes - irrigation).

The calculations carried out according to the proposed methodology showed that under climate change in the arid scenario in the region under consideration, the coefficient of moisture (Cu) will decrease by 6% and the probability of increasing the irrigated area by 23-30% of agricultural land increases, which is necessary for the implementation of the food programme. At the same time, it should be expected that the water availability of the territory as a whole will decrease and, as a consequence, the deficit of irrigation water will increase. In this regard, possible directions of adaptation of irrigated agriculture will be: wider use of low-volume (including drip) irrigation, reuse of prepared drainage runoff and wastewater for irrigation, territorial redistribution of water resources.

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