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Features of optimizing irrigation algorithms under climate change

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FEATURES OF OPTIMIZING IRRIGATION ALGORITHMS UNDER CLIMATE CHANGE

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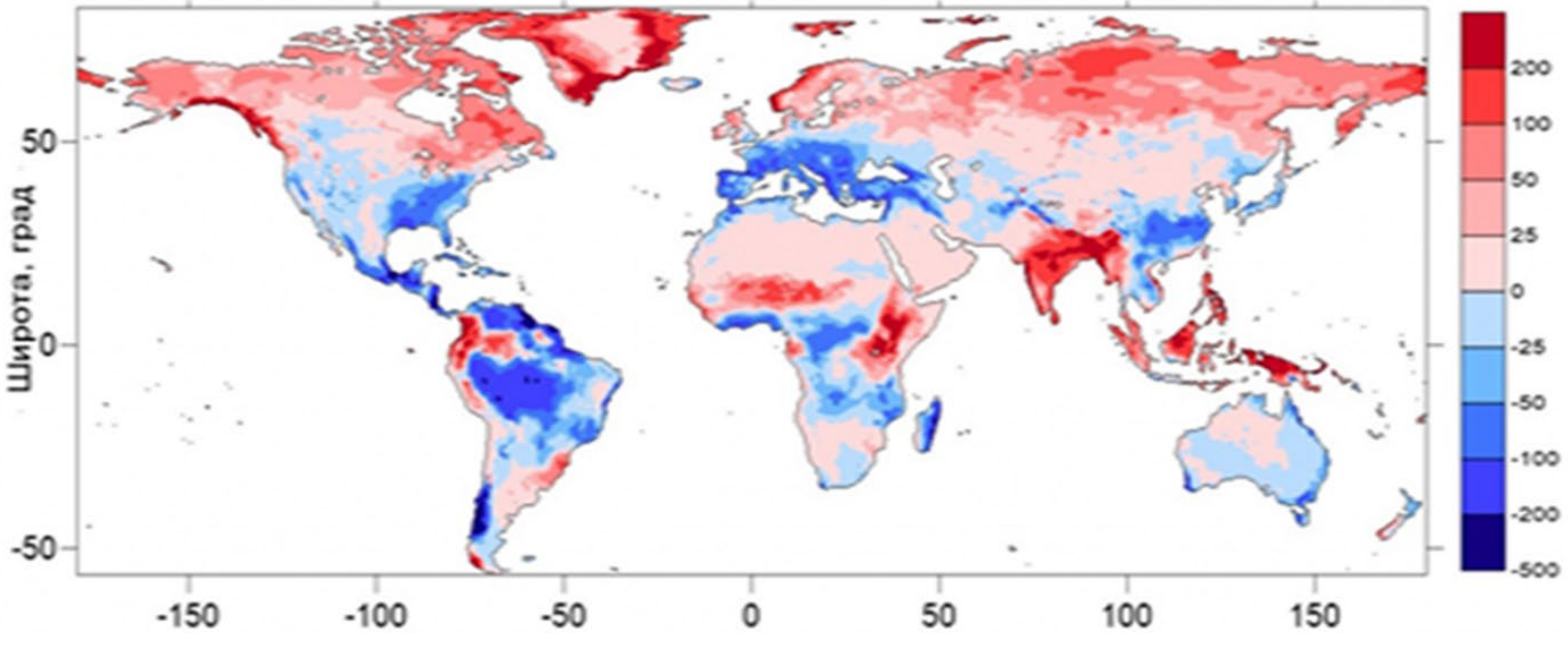
Changes in surface runoff due to climate change



(Main Geophysical Observatory & Institute on Water Problem RAS)

The main factors (regimes) of the external environment that affect the productivity of biological objects and systems

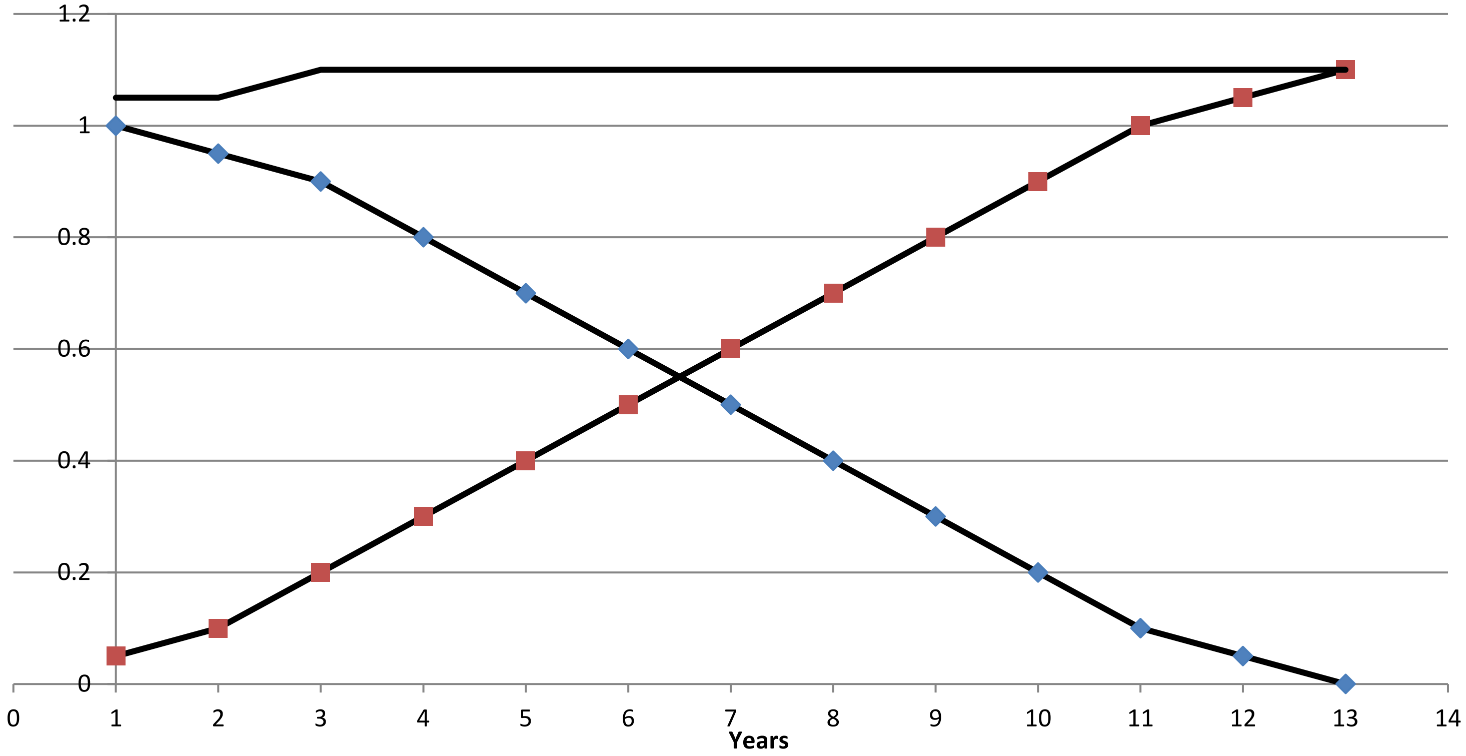
	External regime	The effect of endogenous hydrogen degassing (presumably)
1	Water regime for plants and soil biota	Change in the structure of the pore space (reduction in the volume of the "soil reservoir"); lack of available moisture (drying out) along the degassed contour and over-wetting in the center of the "gap". Formation of water when hydrogen combines with oxygen and the possibility of over-wetting.
2	Thermal regime for plants and soil biota	Change (increase) in thermal conductivity due to destruction of pores, increase in the flow of UV radiation, formation of an “ozone hole”, possible increase in air and soil temperature (non-optimal conditions for soil biota).
3	Gas regime(s) for humans, plants and soil biota	**Reduction of oxygen concentration formed during photosynthesis. "Squeezing out" oxygen and other necessary gases during destruction of pore space (soil reservoirs). Generation of gases during interaction of hydrogen with other substances.**

	External environment modes	Effect of endogenous hydrogen degassing (presumably)
4	Nutritional (chemical) regime for plants and soil biota	Change in soil pH. Change (deterioration) in the absorption of nutrients. Creation of non-optimal conditions for soil organisms (fungi, bacteria, invertebrates, etc.)
5	Radiation regime for plants and soil biota in different spectrum zones	In the projection zones of "ozone holes" the change in the spectrum of solar radiation affects photosynthesis.With an increase in UVR, the creation of "sterile" conditions (death of beneficial, protective microorganisms) on the surface of the soil and plants.

Type of reclamation	Objects and directions of management	Efficiency (economic, social, environmental, climate – ecosystem services)	Necessary actions
4. Precision melioration (2023-2030)	Agricultural plants + creation of optimal conditions for soil biota	Obtaining environmentally friendly agricultural products, preserving and increasing soil fertility	Development of methods and technologies for precision farming systems
3. Phytomelioration (2023 – 2028)	Agricultural plants + restoration of soil biota	Obtaining agricultural products and beginning the restoration of soil biota	Selection of plants with a meliorative regime that promotes more intensive restoration of soil biota
2. Complex melioration (2023-2027)	C-x plants under conditions of non-optimal water, nutrition and thermal regimes	Obtaining high yields of agricultural plants	Reconstruction and conversion to precision melioration control systems
1.Hydromelioration (2023-2025)	Agricultural plants on drained and irrigated lands	Receiving agricultural products	Reconstruction and transfer to complex melioration systems

Type of reclamation	Objects and directions of management	Efficiency (economic, social, environmental, climate – ecosystem services)	Necessary actions
7. Watershed reclamation (2023-2050)	Landscape catena ecosystems of watersheds, ecological networks partially or completely located in a watershed.	Preservation and restoration of ecological networks, maintenance of high-ranking ecosystems. Development of ecosystem water use in the catchment area	Creation of an expert system to substantiate the need and effectiveness of integrated management of land and water ecosystems and watersheds in the context of climate change
6. Ecosystem melioration (2023 – 2050)	Agricultural plants + soil biota + natural ecosystems degrading under climate change	Preservation of existing ecosystems and transition to controlled succession in case of catastrophic scenarios	Development of a concept of actions for various climate change scenarios. (Concept of development of ecosystem melioration)
5. Forest reclamation (2023-2030)	Trees and shrubs on agricultural lands	Increased intensity of carbon sequestration and oxygen “production”	Creation of carbon landfills on agricultural lands, including reclaimed lands

Ecosystem biomass during land reclamation:



Ascending curve – replacement ecosystems;

Descending curve – existing ecosystems.

The total biomass under regulation is the upper line

Models and equations

the model obtained on the basis of representing the dynamics of moisture change by a first-order Markov process

$$W_{i+1} = \alpha_i \cdot W_i + \beta_i + m_i + Z_i,$$

where W_i — humidity at the i-th control step; α_i, β_i - some constants defined for a given step; m_i - management action (analogous to irrigation norm); Z_i - random disturbance of the system.

$$\overline{S_j} = \sum_{t=1}^{j} n_{ij} S_{ij},$$

$\overline{S_j}$ - relative yield of the j-th crop in a given year;
n_{ij} - “weight” of each phase of vegetation is a coefficient showing the influence of moisture in a given phase of vegetation [Shabanov, 1981]

simple productivity model could be used [Golovanov, 2008; Shabanov, 1973]:

$$S_i = \left(\frac{W_i}{W_{opti}}\right)^{\gamma i W_{opti}} \cdot \left(\frac{1-W_i}{1-W_{opti}}\right)^{\gamma i (1-W_{opti}))},$$

S_t - relative productivity at the i-th moment of vegetation; γ_i - is a parameter characterizing the adaptive capabilities of the plant, generally depending on a combination of environmental factors; W_i; W_{opt} - current and optimal moisture reserves in the soil.

$$\sum_{\tau=t^\circ}^{\tau=t_K} p_\tau = 1,$$

t° - vegetation resumption temperature, t_K — end of growing season temperature, τ - discrete interval of increment of effective temperatures over a certain period of time, p_τ - increase in productivity.

Models and equations

$$S_i = g_i(W_{opt} - W_i)^2 + b_i$$

$$\Delta S_i = g_i(W_{i+1} - W_{opt})^2,$$

g_i, b_i - coefficients depending on the biological control object, W_{opti} - optimal humidity value, g_i - function of the temperature factor.

$$N_i = (t_K - t_{\text{cp}i})/\Delta t_i$$

$$m_i = \frac{q_i W_{opt} + A_i B_i - (q_i + A_i)(\alpha_i W_i + \beta_i)}{q_i + A_i + R_i},$$

t_{cp} — actually accumulated effective sum of temperatures by the i-th step; Δt_i - temperature coefficient reflecting the average daily increase on effective temperature; Ni — number of steps remaining until the end of the growing season

where Ai и Bi — constants defined below; Ri - control cost at the i-th step.

Time for irrigation is calculated using the formula:

$$\tau = \frac{F \cdot m}{8.64 \cdot Q \cdot K_{day}}$$

F - field area, Q — machine consumption, $К_{day}$- daily occupancy rate.

Conclusion.

- Analysis of the equations for finding optimal control led to a following conclusion. If the control cost is zero, the required control action is estimated as the difference between the optimum moisture content and the current field moisture content, i.e., it is reduced to the standard procedure used in all irrigation management recommendations for operating irrigation systems.
- The needs for more complex structures arises only when management is carried out with a limited water resource or when it is necessary to take into account all aspects related to irrigation under climate change (loss of soil fertility, sudden droughts, flooding and waterlogging, etc.).
- It is obvious that further development of the irrigation systems operation theory should be carried out on the basis of soil conservation and resource-saving technologies, which will lead to the need for more complex mathematical software (Shabanov, Bondarik; 2027; in press), the use of neural networks and modern tools for monitoring plant habitat factors and soil biota.

Thank You