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# EVALUATION OF EFFICIENCY OF LAND RECLAMATION IN RUSSIA

Research article

## Abstract

According to the natural and climatic conditions, Russia is located in a zone of risky agriculture: there is a precipitate deficit on 80% of arable land, and excessive over moistening on 10% of arable land. This is also complicated by climate aridization. In drought years it is practically impossible to implement intensive agrotechnologies and adaptive-landscape farming systems without the use of land reclamation. Currently, in Russia, the total area of irrigated lands is 4.27 million hectares and 4.8 million hectares of drained lands. The average productivity of irrigated land is 2.9 tonnes of grain units/ha. In the case of land reclamation, it is possible to increase the productive potential by 3-4 times.

The methodology of increasing the productive potential of agricultural lands by irrigation and drainage reclamation based on the energy evaluation of land reclamation activity is proposed. The energy assessment includes the calculation of the bioclimatic potential, the energy assessment of the state of the soil and the vegetation cover. For the energy estimation of land reclamation, a new indicator is proposed a turbulent energy output, the difference between the radiation balance, the energy of soil formation, and the energy accumulated in soil humus and crop production. This makes it possible to predict the productive potential of agricultural land, depending on the amount of energy invested in land reclamation. The proposed approach makes it possible to move from a real evaluation to a unified energy estimate. The calculations of productivity according to the developed method for various natural zones of the European part of Russia are performed. Chernozems showed the greatest productive potential. It reaches 7.7 tonnes of grain units/ha, and in case of irrigation it can increase up to 10-12 tonnes/ha; the productivity of sod podzol and gray forest soils under natural conditions does not exceed 1.3-2.0 tonnes of grain units/ha, while irrigation productivity will increase to 6-8 tonnes of grain units/ha. Irrigation in the semi-desert and desert zones of the European part of Russia allows increasing their productivity up to 5 times.

The proposed method allows selecting the most favorable zoning soils for the reclamation, justifying the crops that ensure the maximum yield in these soil and climatic conditions. The article shows that food security will be ensured during the development of land reclamation in soil and climatic conditions of excessive and insufficient moisture.

**Keywords:** food security of Russia, production potential, melioration, irrigation, drainage, climate change, energy approach, yield forecast.

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# ОЦЕНКА ЭФФЕКТИВНОСТИ МЕЛИОРАЦИИ В РОССИИ

Научная статья

## Abstract

По природно-климатическим условиям Россия находится в зоне рискованного земледелия: дефицит осадков наблюдается на 80 % пахотных земель, а избыточное переувлажнение на 10 % пашни. Это осложняется аридизацией климата. В засушливые годы без применения мелиорации практически невозможно реализовать интенсивные агротехнологии и адаптивно-ландшафтные системы земледелия. В настоящее время в России площадь орошаемых земель составляет 4,27 млн га, осушаемых земель 4,8 млн га. Средняя продуктивность на орошаемых землях 2,9 т з.ед./га (зерновых единиц). При гидромелиорации земель возможно увеличить продукционный потенциал в 3-4 раза.

Предложена методология повышения продукционного потенциала сельскохозяйственных угодий оросительными и осушительными мелиорациями на основе энергетической оценки мелиоративной деятельности. Энергетическая оценка включает расчет биоклиматического потенциала, энергетическую оценку состояния почвы и растительного покрова. Для энергетической оценки мелиорации предложен новый показатель – *турбулентная энергоотдача*, что представляет собой разницу между радиационным балансом, энергией почвообразования и энергией, аккумулированной в почвенном гумусе и растениеводческой продукции. Это позволяет прогнозировать продукционный потенциал сельскохозяйственных земель в зависимости от количества вкладываемой энергии при проведении мелиораций. Предлагаемый подход позволяет перейти от вещественной оценки к унифицированной энергетической оценки. Выполнены расчеты продуктивности по разработанной методике для различных природных зон Европейской части России. Наибольший продукционный потенциал у черноземов. Он достигает 7,7 т.з.ед./га, а при орошении может увеличиться до 10 - 12 т.з.ед./га; продуктивность дерново-подзолистых и серых лесных почв в естественных условиях не превышает 1,3-2,0 т.з.ед./га, при орошении продуктивность увеличится до 6-8 т.з.ед./га. Орошение в полупустынной и пустынной зонах Европейской части России позволит до 5 раз увеличить их продуктивность.

Методика позволяет выбрать наиболее благоприятные для проведения мелиорации зональные почвы, обосновать сельскохозяйственные культуры, обеспечивающие максимальный выход продукции в данных почвенно-климатических условиях. В статье показано, что продовольственная безопасность будет обеспечена при развитии мелиорации в почвенно-климатических условиях избыточного и недостаточного увлажнения.

**Ключевые слова:** продовольственная безопасность России, продукционный потенциал, мелиорация, орошение, осушение**,** изменение климата, энергетический подход, прогноз урожайности.

## 1. Introduction

The total area of reclaimed lands is 9.44 million hectares, 4.67 million hectares of irrigated lands, and 4.77 million hectares of drained lands in Russia. The majority of all reclaimed lands are located in the European part of Russia, even now in the south of the country they already experience the lack of water for irrigation, especially in Kalmykia and the Caspian lowland. Irrigation in this region is an essential condition for the production of agricultural products. Currently, in Russia, crop yields are four times lower than in the UK and Germany and two times lower than in China (Figure 1). This is due to the lack of reclaimed lands and their high productivity. The average productivity of irrigated land is 2.9 tonnes of grain units/ha, 2.2 tonnes of grain units/ha of drained lands.

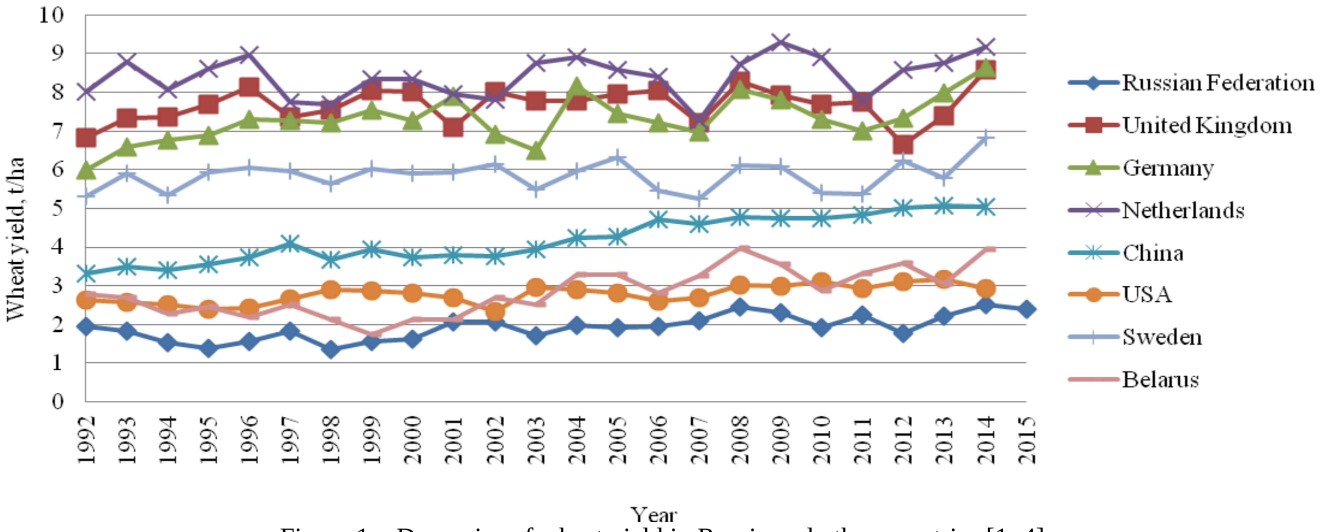


Figure 1 – Dynamics of wheat yield in Russia and other countries [1, 4]

The area of reclaimed land used is 5.8% of the arable land area. We propose a methodology for calculating the productivity of agricultural land with the possible development of hydro technology in Russia.

## 2. Methods

The assessment of the efficiency of the irrigation and drainage systems is carried out on the basis of the energy balance and depends on the radiation balance, anthropogenic energy, including agrotechnical, meliorative and other necessary measures aimed at harvesting. The balance takes into account the energy received from agricultural products, the energy stored in the soil humus and the energy expended on humus formation, as well as that part of the energy that is dissipated, i.e., is consumed unproductively for the specified system. The efficiency of the system increases with decreasing scattering energy [8]. In order to assess the energy efficiency of agricultural land as a natural system, we propose a new indicator – a turbulent release of energy, which is defined as the difference between the radiation balance, the energy of soil formation and energy, soil humus and agricultural products:

$$J = R - Q_S - BEP_H - BEP_P \, , \tag{1}$$

where J is the turbulent release of energy, kJ/cm$^2$; R is the radiation balance, kJ/cm$^2$; Qp is energy directed to the formation of soil humus, kJ/cm$^2$; $BEP_G$ is the energy accumulated in soil humus, kJ/cm$^2$; $BEP_P$ is the energy accumulated in crop production, kJ/cm$^2$.

According to formula (1), it is possible to estimate the amount of energy that dissipates and is not involved in agrocenosis, which reduces the system's efficiency. Schematic diagram of the energy balance is shown in Figure 2.

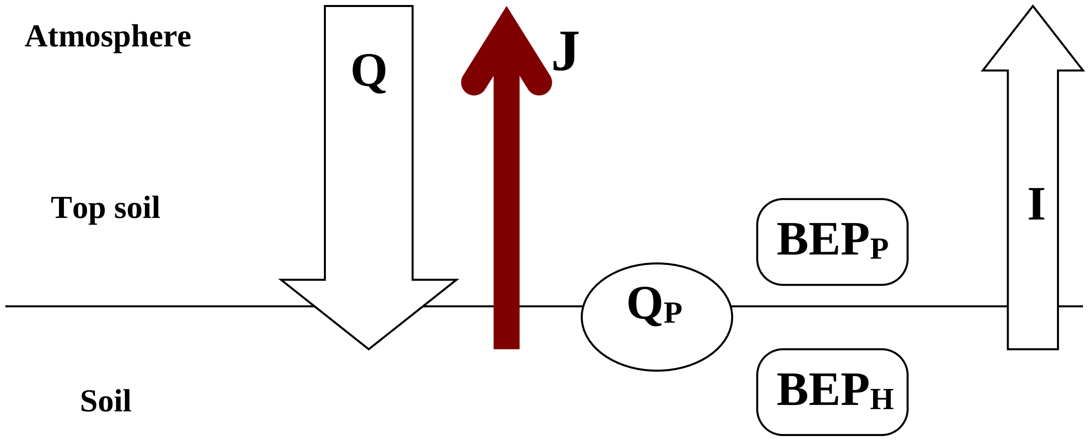


Figure 2 – Energy balance diagram "Atmosphere – Vegetation layer – Soil."

Let us consider the definition of the individual components of formula (1). The radiation balance can be determined by the formula [2]:

$$R = Q \cdot (1 - \alpha) - I, \tag{2}$$

where Q is the total short-wave radiation, kJ/cm$^2$; α is albedo, in unit fractions; I is the effective radiation, kJ/cm$^2$.

To assess the energy state of the soil and its changes, depending on the incoming precipitation, we use the dryness index:

$$\overline{R} = \frac{R}{LO_C}, \tag{3}$$

where L is the latent heat of vaporization, a constant value equal to 2.256 KJ/cm$^2$; $O_C$ is the sum of long-time average annual precipitates,

The energy of soil formation was estimated from the dependence [3]:

$$Q_n = R \cdot e^{-0,47 \cdot \frac{E}{Oc}}, \tag{4}$$

where E is the evaporation capacity, mm, E = 19*R$^{0.67}$. The rest of the notation is given above.

In carrying out hydro technical melioration in order to create the required water regime for the growth of the agricultural crops, the magnitude of $O_c$ is taken to be equal to the water consumption of the crop.

The energy accumulated in soil humus and crop production can be estimated through bioenergy potential (BEP). The methodology for calculating the bioenergy potential of any organic matter, including soil organic matter ($BEP_H$) and plant phytomass ($BEP_P$), is presented in the work of O.B. Khokhlova [9]. Depending on the ratio in the soil of the humate and fulvate humus [10], the bioenergetic potential changes. For sod podzol soils, BEPg is 3.95 GJ/t, and for the most fertile black soil, it is 5.8 GJ/t. The amount of energy accumulated in the crop yield ($BEP_P$) was calculated for grain and is 4.8 GJ/ton.

The productivity of agrocenosis can be determined by the formula [7]:

$$P = S \cdot CL, \tag{7}$$

where P is the potential productivity of vegetation biomass for given soil-climatic conditions, t/ha of air-dry matter; S is the soil index, which determines fertility; CL is the coefficient of climate favorableness, which directly depends on the magnitude of the radiation balance, precipitation and temperature, irrigation rate and evaporation.

Irrigation changes the radiation balance of the territory due to additional moistening or drying, the dryness index changes and the productivity of the agrocenosis increases, which also depends on soil fertility, the integral indicator can be determined by empirical dependence [7]:

$$S = 6,4(G_{GK} + 0,2G_{FK}) / 600 + 8,5\sqrt[3]{NPK} + 5,1e^{-|H_z - 1|/4}, \tag{8}$$

where 600; 8.5; 5,1 are coefficients; Ggk and Gfk are the values of the humate and fulvate humus in the soil respectively, t/ha; N, P, K is the fraction of the optimal value of nitrogen, phosphorus, and potassium in the soil; Hg is hydrolytic acidity, meq/100 g.

The model considered is applicable for zonal soil types, since it takes into account a large set of characteristics and basic properties of soils. The performed calculations have shown that the comparison of the results obtained by the formula (8) correlates with the yield of the crops at the sort sites.

## 3. Results and discussion

Calculations of the magnitude of turbulent energy output in accordance with formulas (1-4) under natural conditions and during irrigation and drainage meliorations for zonal soils have shown that it is possible to increase productivity by decreasing the value of turbulent energy transfer: in the wetland zone, by dehumidification, and in the zone of unstable and insufficient moistening – by irrigation (Figure 3).

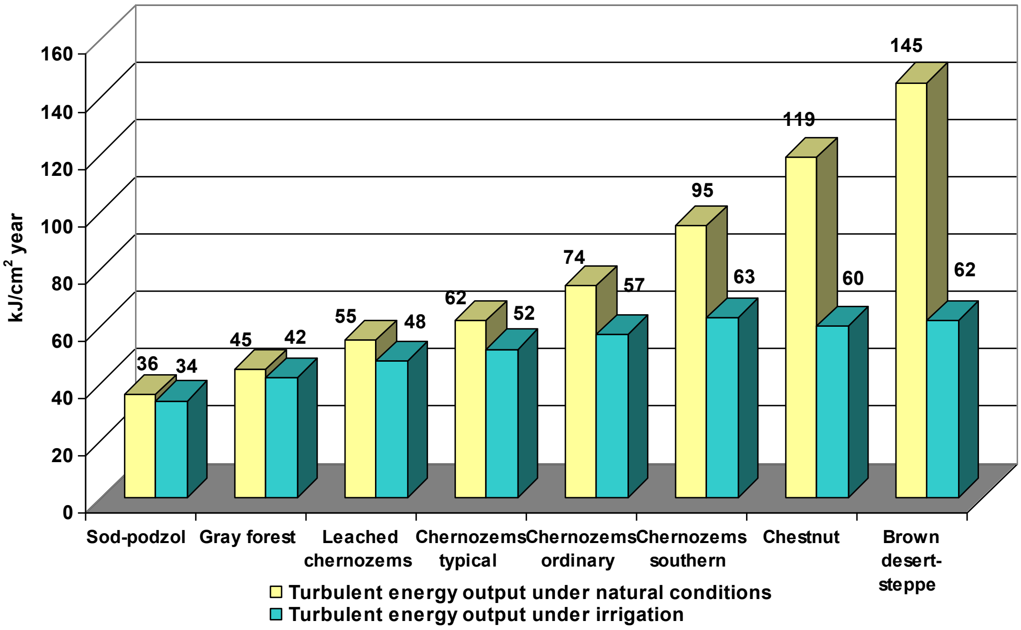


Figure 3 – The importance of the turbulent release of energy under natural conditions and during irrigation for zonal soils in the European part of Russia

The greatest efficiency of irrigation is noted for the regions of development of chestnut and brown semi-desert soils. At these soils, the release of energy decreases from 118,3 – 144,79 to 60,83 kJ/cm$^2$ at irrigation. In typical chernozems, the yield is practically balanced, and the yield is 62-52 kJ/cm$^2$, which indicates a large energy reserve of the soil. For these soils, irrigation is necessary only in certain years, when natural precipitation is not enough.

The proposed methodology makes it possible to evaluate the effectiveness of irrigation or drainage in various climatic and soil conditions. Calculations have shown, and practice has confirmed the high efficiency of hydro-technical melioration for zonal sod podzol, chestnut and brown semi-desert soils of the European part of Russia.

The calculation of productivity was carried out for natural conditions and during irrigation for the leading crop rotation in specific soil and climatic conditions. When calculating by formula (8), the zonal soil parameters were adjusted to the optimum limits for the amount of humus and basic nutrients. The features of the properties of the leading crop of crop rotation and the applied system of farming are assessed. The calculations are performed in grain units on average for a crop rotation for zonal soils in the European part of Russia. Calculation of productivity, performed according to formulas (7-8) for natural conditions and irrigation of zonal soils in Russia is shown in Fig. 4.

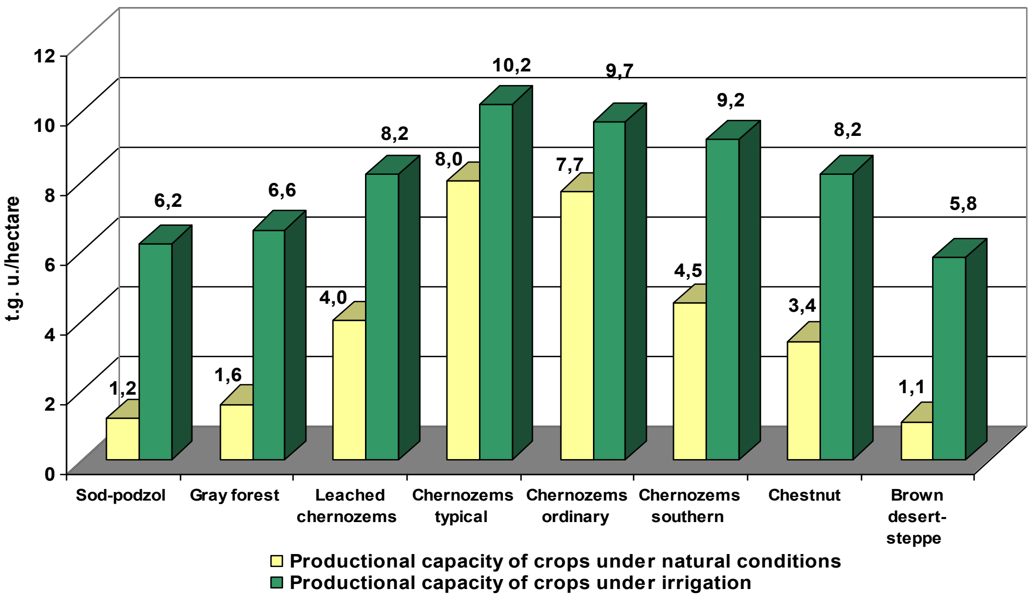


Figure 4 – Change in production potential in the irrigation of zonal soils

As one can see from the figure, the most productive soils in natural conditions are ordinary chernozems, their production potential reaches 7.7 – 8 tonnes of grain units/ha, and with irrigation it can increase to 9.7 – 10.2 tonnes of grain units/ha; the productivity of sod-podzol and gray forest soils under natural conditions does not exceed 1.3-1.6 tonnes of grain units/ha, however, when reclamation is carried out, the productivity may increase to 6-8 tonnes of grain units/ha. Thus, irrigation makes it possible to increase the productivity in the acute drought zone by almost five times, and drainage in the zone of excessive moistening ensures a yield increase of 3-5 times.

For example, in 2011, when reclamation was carried out in the Klyuchevsky district of the Altai Territory, the yield of the green mass of corn for silage at 47.6 tonnes/ha was obtained from the irrigated area of 1800 hectares, which is 4.7 times more than in rainfed lands. In the "Josefov" farm of the Rostov region, with an irrigated area of 230 hectares, 70 tonnes per hectare of onion per hectare and 60 tonnes per hectare of vegetables from a 260-hectare area, which is 4-5 times higher than without irrigation.

## 4. Conclusion

A methodology is proposed for substantiating the development and location of hydro-technical melioration, depending on climatic and soil conditions. The methodology is based on the analysis of the energy balance of agrocenosis, which takes into account the supply of radiant energy and its expenditure on the processes of soil formation and crop formation. It is shown that, depending on the soil-climatic conditions, the efficiency of the incoming energy is different. The most favorable conditions for the cultivation of crops are the zone of distribution of chernozem soils, in which without regular irrigation it is possible to obtain up to 8 tonnes of grain units per hectare, and in case of irrigation, the production potential may increase up to 10-12 tonnes of grain units/ha. In the zone of excessive moistening in order to obtain 5-6 tonnes of grain units/ha, it is necessary to drain it. In the southern steppe and semi-arid zone under irrigation, it is possible to achieve yields of up to 6-8 tonnes of grain units/ha or 3-5 times higher than without irrigation.


## Conflict of Interest

None declared.

## Конфликт интересов

Не указан.


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