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FORMATION OF FERTILITY AND PRODUCTIVITY INDICES OF RECLAIMED SOILS UNDER CONDITIONS OF REGIONAL CLIMATE CHANGE OF THE SOUTH OF UKRAINE

SUMMARY

The paper summarizes the results of research on the dynamics of changes in climatic parameters (air temperature and rainfall) over the 70-year period (the end of the XX and the XXI centuries) in the agro-soil zones of south of Ukraine; the main factors of the negative influence of elevated temperatures on properties of soils are revealed; the optimal parameters of agro-technical measures for the reduction of the risk of insufficient soil moisture and increase of agricultural stability are substantiated.

The represents the methodological approaches and the results of the evaluation of integrated space-time modelling of the heterogeneity of changes in agrochemical properties of soils in the steppe zone (on the example of Kherson region of Ukraine) under conditions of regional climate change. The paper evaluates the changes of soil-climatic potential of agricultural lands depending on climatic conditions and suggests their comparative estimation by fertility; it determines the total agrochemical potential of dry-steppe soils and develops the gradation according to their ability to maintain steady yields of grain crops.

The paper simulates the changes in energy expenditure on soil formation during the development of irrigated agriculture.

The study develops the models and the maps of productive moisture content in soils for demanding and less demanding crops for the development and implementation of reclamation measures aimed to increase soil fertility of the dry-steppe zone.

The paper suggests the system of nature protection measures for management of agricultural lands considering the qualitative estimation of soils (including irrigated lands) to determine the changes in the potential of reclaimed soils, increase informational content and objectivity of management decisions concerning the development of land reclamation measures and optimization of agricultural land use under conditions of regional climate change.

Keywords: climate, soils, fertility, productivity, irrigation, yield.

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INTRODUCTION

The sensitivity of agricultural productivity to climate has not been sufficiently quantified (Liang, 2017). When adapting agricultural activity to the conditions of global and regional climate change in the dry steppe zone of Ukraine for the characterization of soil potential and the design of agricultural crops, the regularities of forming the soil formation process, fertility and productivity of reclaimed soils are topical issues.

In the context of regional climate change, the work of many scientists in Ukraine is devoted to irrigation: V.V. Medvedev, S.A. Balyuk, M.I. Romashchenko, V.O. Ushkarenka, V.V. Gamayunova, A.O. Limar, F.M. Lisetskogo, O.V. Morozova, V.V. Morozova V.I. Pichura and others (Medvedev, 2014; Morozov, 2013). Increasingly there is a need to develop a management system for reclaimed agricultural land (primarily irrigated), taking into account changes in the main fertility and productivity indicators of soils.

The *purpose* of the study is to determine the patterns and characteristics of the formation of fertility and productivity indicators of the reclaimed soils of the dry-steppe zone of Ukraine in conditions of regional climate change (for example, Kherson region).

Research objectives:

- to carry out a retrospective analysis of climate change over the past 70 years and to develop a classification of years by climatic indicators for the dry steppe zone;
- to carry out the zoning of the land suitability of the Kherson region for the cultivation of crops with average annual content of productive moisture;
- to study the formation of levels of crop yields by climatic characteristics of years;
- to develop a spatial model of the current state of suitability and potential of land for agrochemical properties of soils for cultivating and designing the level of crop yields.

Objective of study - processes of spatial-temporal formation of fertility and productivity of reclaimed soils of dry-steppe zone in conditions of regional climate change. Subject of research are soil-climatic indicators of fertility and productivity of agricultural land.

MATERIAL AND METHODS

We used standardization of parameters of agroclimatic conditions for growing of agricultural cultures by the method of Medvedev (2014) and normalization of parameters of soil fertility indices in relation to the cultivation of agricultural crops by the method of Karmanova (1980).

To develop a modern classification of years by climatic indicators, spatio-temporal modelling of crop yield formation, transformation of fertility of irrigated and non-irrigated soils, conducting ground-climatic grounding of ground potentials, a database of statistical data was created and analysed: the analysis of the dynamics of climatic indicators (for the period 1945-2015 years); the dynamics of irrigation areas, weighted average irrigation rates, the efficiency

of water use (volumes of water supply and water intake), the dynamics of yield of major crops on irrigated lands; agrochemical indicators of soil fertility.

RESULTS AND DISCUSSION

According to the analysis of changes in the main climatic indicators; air temperature, amount of atmospheric precipitation (Fig. 1, 2), the cyclic component of the average annual air temperature is 8 years. The average authenticity of the settlement data is 94%. The results of forecasting determined that in the period 2017-2022, a gradual cyclical increase in the average annual temperature of air with an average intensity of 0.08 °C per year is expected. In relation to the amount of annual precipitation, there is a stable tendency to increase the serene-periodic value in accordance with the multi-year norm. According to the results of generalization of long-term climatic data, a classification is proposed on the availability of atmospheric precipitation and air temperature in the dry steppe zone of Ukraine (Table 1).

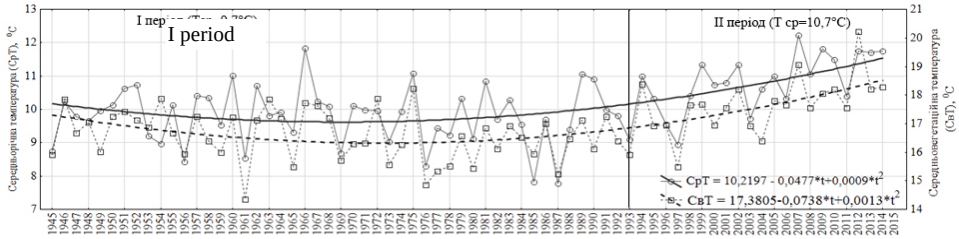


Figure 1. The long-term dynamics of air temperature (1945-2015), °C

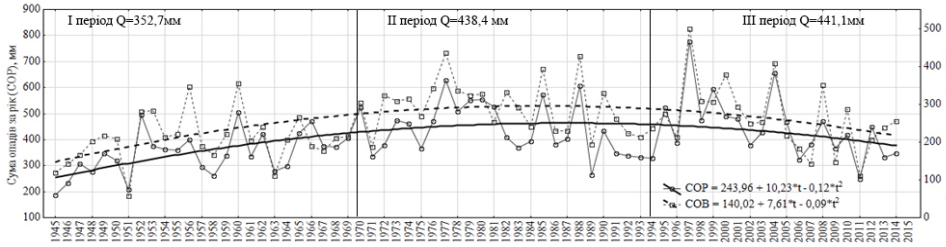


Figure 2. Long-term dynamics of atmospheric precipitation (1945-2015 years), mm

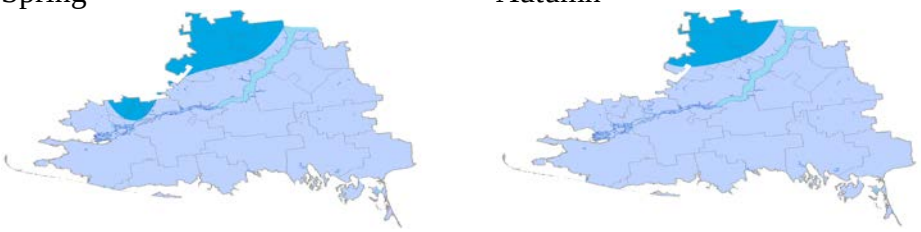
Table 1. Characteristics of years for the provision of atmospheric precipitation and air temperature in the dry steppe zone of Ukraine

Characteristics of years on humidity	Atmospheric precipitation, mm		Characteristics of years by air temperature	Air temperature, 0C	
	multi-year rule 450 mm	during the growing season (long-term norm of 280 mm)		in a year	during the growing season
Dry	400	250	Cold	< 8,5-9,5	<15-16,0
Medium	401-499	251-309	Moderate	9,5–11,0	16,0-17,5
Moist	over 500	over 310	Warm	11,0-12,0>	17,5-18,0>

The zoning of the land suitability of the Kherson region by average annual content of productive moisture (Fig. 3) is proposed. As a result of the research, the zoning of land suitability for the cultivation of insignificant crops (winter wheat, spring barley) has also been developed, with an average annual content of productive moisture in a 0-20 cm layer.

Factors such as humus, nitrification nitrogen, exchangeable potassium, mobile phosphorus, exchangeable sodium, soil pH, amount of annual precipitation, average annual air temperature, water supply were used to form a winter wheat yield pattern on irrigated lands. In dry years (2007, 2011), the yield of winter wheat under irrigation in the region ranges from 1,9 to 4,79 t/ha.

Spring Autumn



- < 30 unacceptable (worse)
-30-40 admissible (satisfactory)

Class of land suitability	Area of arable land	
	%	mln.ha
Spring		
optimal conditions**	0	0
admissible (satisfactory)***	14,7	0,25
unacceptable (worse)****	85,3	1,45
Total	100	1,70
Autumn		
optimal conditions**	0	0
admissible (satisfactory)***	12,5	0,21
unacceptable (worse)****	87,5	1,49
Total	100	1,70

Areas of eligibility of arable land for the cultivation of demanding * crops for the average annual content of productive moisture (layer 0-20 cm). * - In demanding crops, the content of productive moisture include: corn for grain, sunflower, potatoes; ** - optimal conditions ensure implementation of adaptive potential of agricultural crops to the content of productive moisture; *** - acceptable conditions - reduction of potential yield by 20-30%; **** - Invalid conditions -30-50%.

Figure 3. Distribution of land suitability of the Kherson region for growing demanding crops on the criterion of average annual content of productive moisture in a layer 0-20 cm before sowing, mm.

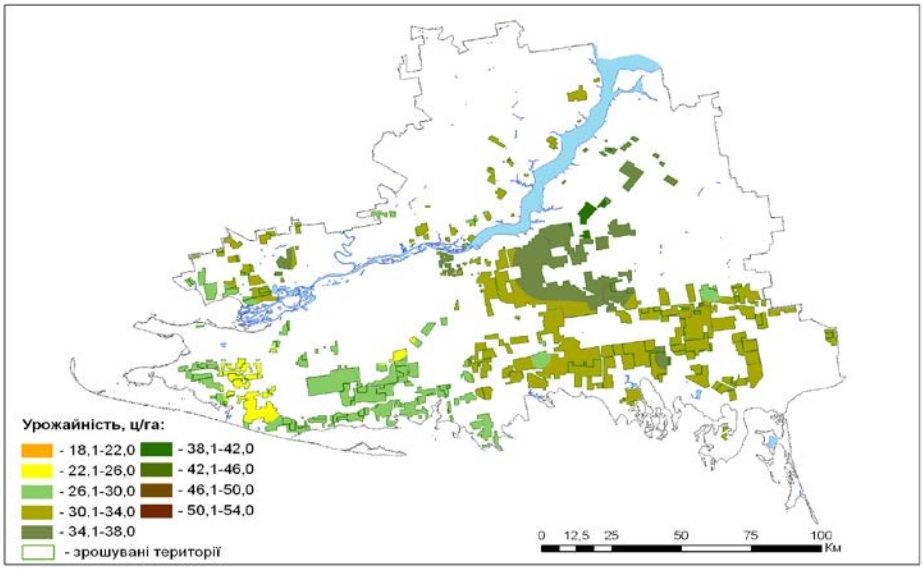
The multiple coefficient of correlation of the regression model (r=0,90) indicates a close correlation between yield and investigated factors. The greatest influence in the dry years on the formation of winter wheat yields is the amount of precipitation, water supply and air temperature. Due to high dry air temperatures in irrigated lands, increased content of exchangeable sodium and changes in soil pH significantly reduce yields (Fig. 4).

In the middle years (2009, 2012), winter wheat yields in areas ranged from 2.15 to 3.76 t/ha (r=0,93). In damp years (2008, 2010), the yield of winter wheat in the regions of the region varies from 2,47 to 4,72 t/ha (r=0,98). In the formation of winter wheat yield in the presence of precipitation significantly increases the role of humus, nitrogen, potassium, phosphorus (Fig. 4).

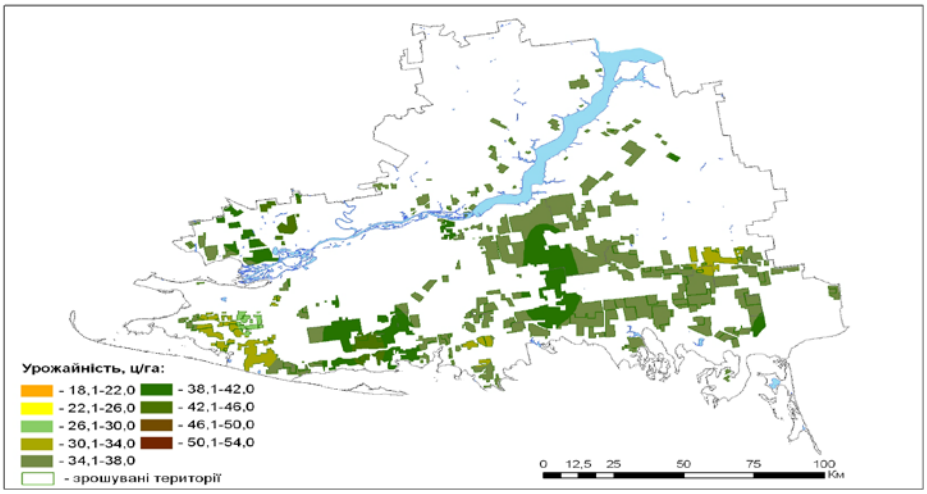
Long-term research has determined the probability of repeatability of years with weathering, which allows predicting the yield of winter wheat (Table 2).

Table 2. Probability of repetition of years on the availability of atmospheric precipitation

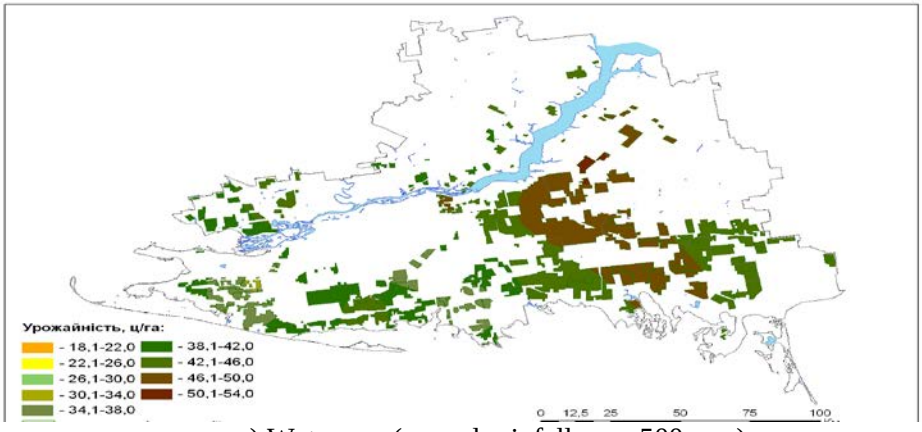
Characteristics of years on humidity	Probability of year in terms of humidity,%	Average yield of grain per region, t / ha	
		all the land	incl. irrigation
Dry	39	2,4	2,0-3,0
Medium	33	2,5	3,0-4,0
Moist	28	2,7	4,0-5,0



a) Dry years (annual rainfall up to 400 mm)



b) Mid-dry years (annual precipitation 401-499 mm)



c) Wet years (annual rainfall over 500 mm)

Figure 4. Cartogram of the yield of winter wheat grains on irrigated lands of the Kherson region, depending on the classification of years for the provision of atmospheric precipitation

A spatial analysis of the distribution of the region's lands according to a comprehensive assessment of the nutrient content has been carried out. It is determined that 75% of the lands located in the northwest and southeastern parts of the Kherson region have satisfactory, favorable and very favorable agrochemical conditions for the cultivation of grain crops, 25% of the land is predominantly in the southwestern part and the coastal zone of the Dnipro River, unsatisfactory (20,6%) and very unsatisfactory (4,4%) agrochemical properties of soils for cultivating grain crops (Figure 5).

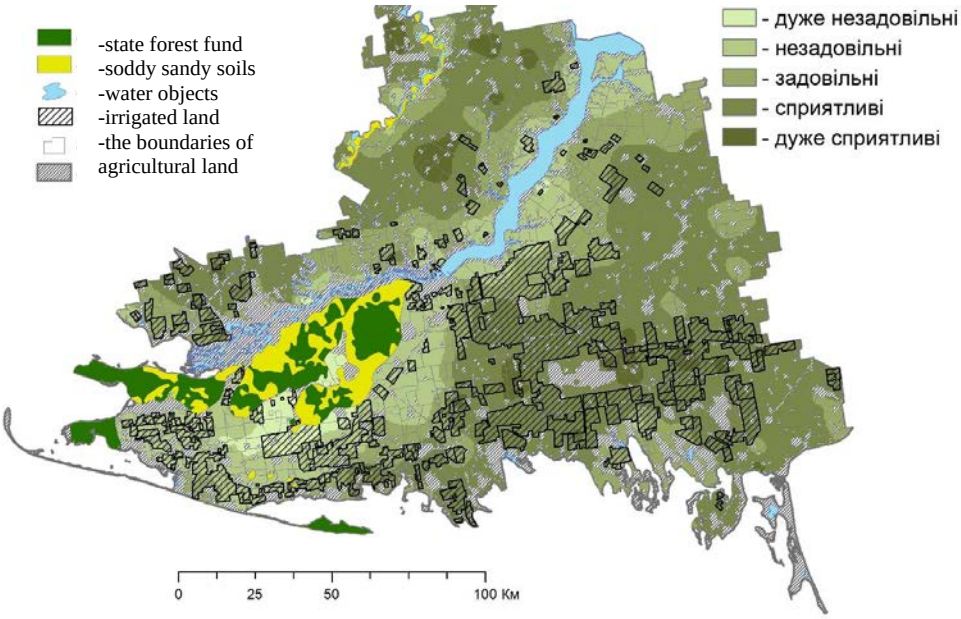


Figure 5. Agrochemical zoning of agricultural lands of the Kherson region on the suitability of cultivating grain crops

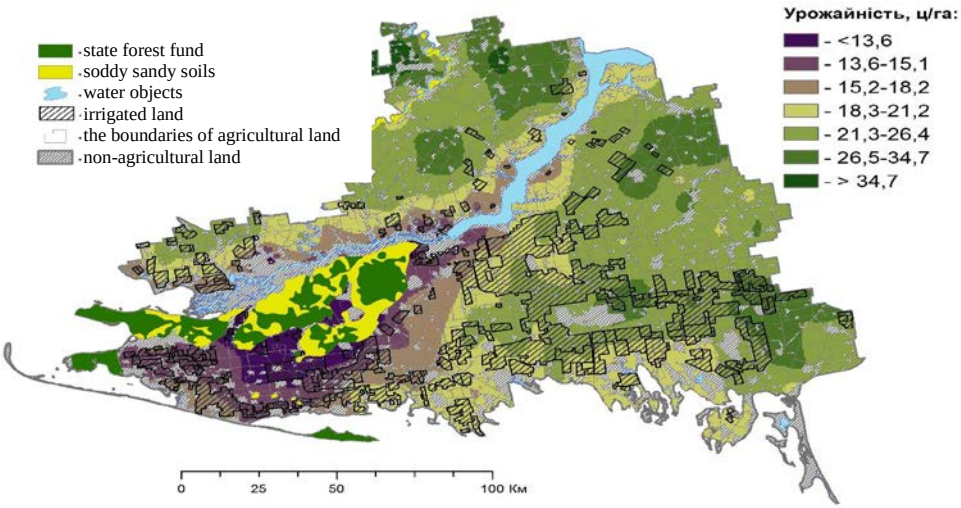


Figure 6. Cartogram of potential yield of grain crops depending on the content of humus (for example, Kherson region)

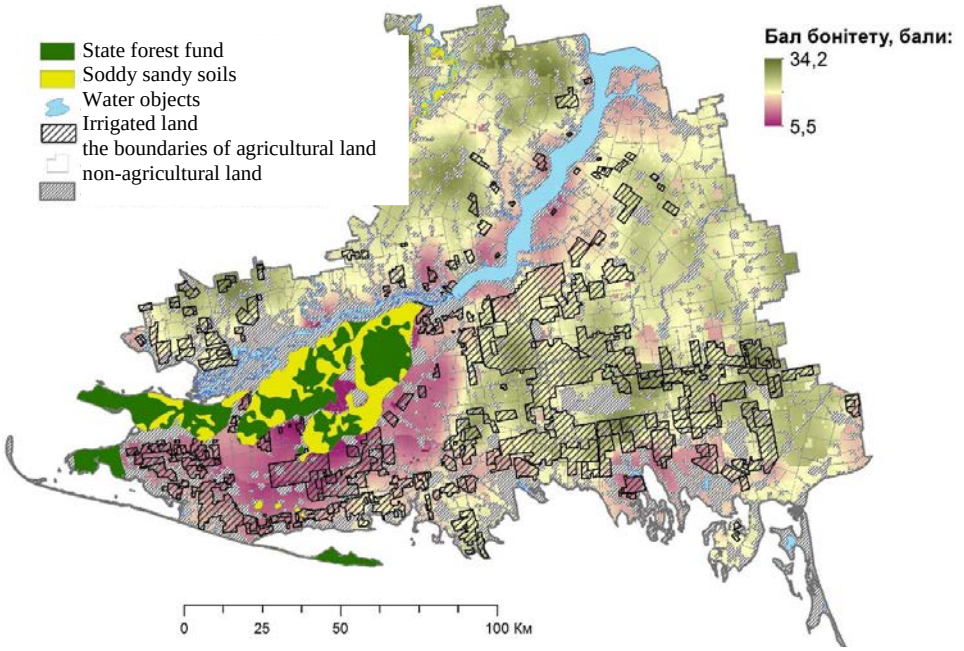


Figure 7. Soil-climatic quality of agricultural land for cultivating grain crops (according to Karmanova I.I.)

Accordingly, the classification proposed by Academician V.O. Ukhartan created a spatial model and determined the areas of formation of the design crop of grain crops depending on the content of humus. It was determined that 56,5% of the territory of the project crop yields is 1,8-2,6 t/ha; 29,77% within the limits of 1,3-1,8 t/ha and 13,74% -2,6-3,6 t/ha. The results of the research confirm that the land of the Kherson region is favorable for growing and obtaining stable yields of grain crops (Fig. 6).

As a result of the research, the ballooning point in the system of economic land valuation was determined and an energy assessment of the soil-forming process orientation under the conditions of regional climate change was carried out (Fig. 7).

The determined agitation of soils is a continuation of complex agrochemical research. As a result of GIS-modeling, calculation of Bonity points for growing of grain crops on agricultural lands of Kherson region was carried out. These data are typical for the soil and climatic conditions of southern Ukraine.

The correlation dependence of the grain crop yield on the irrigated ($r = 0.81$) and non-irrigated lands ($r = 0.88$) on the yield of grain crops was determined (Fig. 8). The methodology used in the bioenergy approach allows us to model scenarios of climatic influences (through heat and moisture provision),

expressed in energy equivalents, on the spatial and temporal trends of soil development. The correlation dependence of formation of irrigation regime on the amount of precipitation during the growing season is determined. An increase in rainfall contributes to a decrease in the weighted average irrigation rate.

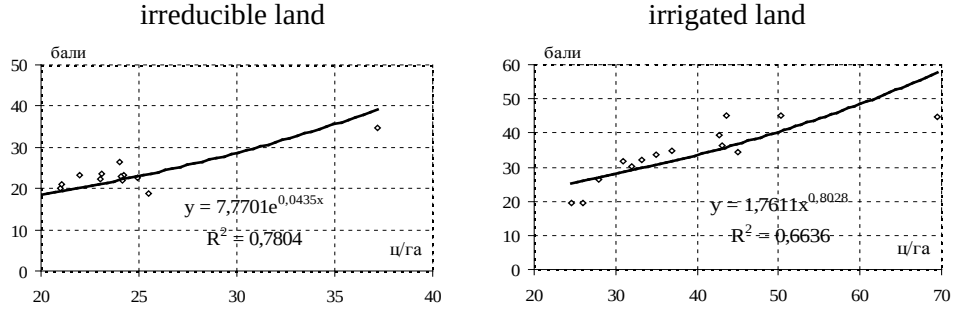


Figure 8. Dependence of the ground of the ground bonus on the soil-climatic potential of grain crop yields

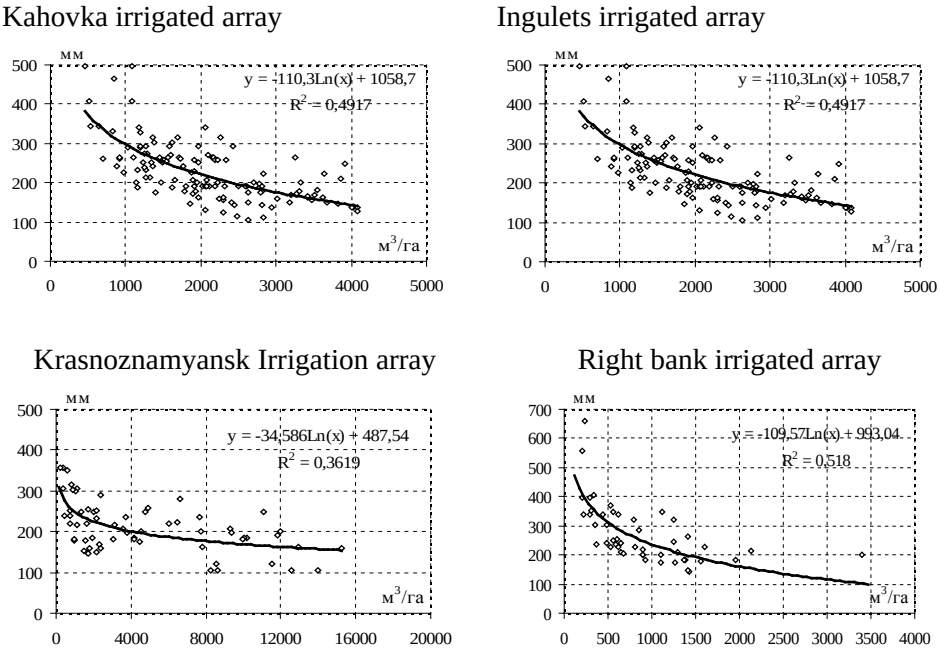


Figure 9. Dependence of the irrigation rate value on the amount of atmospheric precipitation during the growing season on the irrigated massifs of the Kherson region

CONCLUSIONS

According to the results of the research, maps of the content of productive moisture in the soils of the Kherson region were created and the conditions of cultivation of agricultural crops were determined for the actual availability of productive moisture in the layer of soil 0-20 cm:

- For the cultivation of demanding crops: in the spring, in the western and north-western parts of the region, the average annual content of productive moisture is characterized as acceptable and covers an area of 0.25 million hectares (15% of the total area); in the direction to the southeast, the supply of available moisture is reduced and is characterized as inappropriate by an area of 1,45 million hectares (85%). Areas with optimal conditions for growing crops on the content of productive moisture in a layer of soil 0-20 cm - are absent.

- For the cultivation of insignificant crops: in the spring, in the western and north-western parts of the region, the average annual content of productive moisture is within optimal limits and covers an area of 0,25 million hectares (14,7% of the total area); To the southeast, the supply of available moisture is reduced and is characterized by a permissible area of 1,45 million hectares (85,3%). Areas with inadmissible parameters of cultivating crops on the content of productive moisture in a layer 0-20 cm-absent.

The potential yield of grain crops in agricultural land of Kherson region is determined. As a result of spatial modelling, it has been established that 56,5% of the land in the oblast can provide potential yield formation in the range of 1,8-2,6 t/ha; 29,77% within the limits of 1,3-1,8 t/ha and 13,74% -2,6-3,6 t/ha. According to agrochemical properties, agricultural lands of the region are quite favorable for growing and obtaining stable yields of grain crops.

It was established that the ground of the land for the cultivation of grain crops is in the range of 5,5-34,2. The highest potential is characterized by soils located in the central, central-eastern and north-western parts of the region with a ball of bonite 20.1-34.2, which occupy about 66% of the territory.

Investigations have determined the dependence of the irrigation rate on the amount of precipitation during the growing season on irrigated massifs of the region. The correlation dependence of formation of irrigation regime on the amount of precipitation during the growing season is determined. An increase in rainfall reduces the weighted average irrigation rate

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