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Foundation of irrigation restoration based on scenario simulation of potential productivity of agricultural lands*

The purpose. To estimate the potential productivity of agricultural lands was based on different scenarios simulation of water and land use on a pilot area of Kherson district for reasoning restoration of irrigation on-site. **Methods.** Analytical, statistical, immitation (simulation), method of system analysis. **Results.** As a result of typization of pilot area it was allocated typological zones with similar soil and climatic conditions. Simulation of potential land productivity on each typological zones were done by dynamic model of production process WOFOST on example of maize. The assessment of land productivity was done on the basis of the simulation results of water and land use scenarios with different natural and farming conditions. **Conclusions.** The simulation method of water and land use scenarios is allowed to consider different influence on the formation of potential land productivity under different natural and economic conditions, and to select economically profitable and environmentally safe option of restoration of irrigation.

Key words: *territory typization, simulation, potential maize yield, land productivity, water and land use scenarios.*

The importance in research of current water and land use conditions on agricultural territory is associated with Government Resolution about restoration and sustainable use of irrigated lands, that guarantees food security [11]. Literature analysis shows a previous research of potential level of agricultural lands in the Kherson district were based mainly on the data from point ground-based observation. The data of crop development and their level of yield were getting from stationary experiments from agronomic and weather stations and experimental farms. At the same time, it was not possible to estimate a spatial and temporal variability of crop productivity on the territories under current climate changes, soil types and water and land use conditions as a complex. The only previous spatial map of agricultural lands productivity [6] was built from general and interpolar data of real yield of the best farms in Kherson district. That data of crop yield was linked to specific soil, climatic and environmental conditions. However, those indexes are slightly low and do not characterize the potential level of crop yields under current soil and climatic conditions, environmental changes [2, 3] and water and land use stage.

The purpose. To estimate the potential productivity of agricultural lands was based on different scenarios simulation of water and land use on a pilot area of Kherson district for reasoning restoration of irrigation on-site.

Materials and methods. Research was carried out for the Kherson district in general and separately on the pilot territory of two regions (Khahovka and Chaplynka). Analytical studies were included analysis and systematization of data on the spatial and temporal climate variability, conditions of water and land use; testing and adaptation of foreign and national methods to simulate and evaluate a potential productivity of agricultural lands for further using in irrigation scheduling tasks in the Southern part of Ukraine. For map constructing, that are based on results of researches, was applied a GIS-technology (software component of ArcGIS).

Results. A pilot territory has got varied and complex natural, social and environmental conditions. At the same time the changes and problems that are arisen with using of water and land resources, are

similar for the whole Kherson district and for the whole irrigated zones in the Southern Part. According to work purpose the simulation of potential land productivity was originally done a typization of agricultural lands [8]. As a result, by using GIS-technology program were built and combined maps of representative weather stations and soil types, followed by the determination of 12 typological zones with similar climatic and soil conditions within each administrative region [7]. Then, for each selected typological zones was simulated the potential yield of maize (three hybrids groups: early-, medium- and late-ripening) with and without irrigation conditions [5]. Maize is a promising crop, has got large areas of cultivation and under irrigation provides a significant yield [10]. For simulation of crop yield we used a dynamic model WOFOST [1]. According to the results of yield simulation for 2000-2013 years was determined that average index of potential productivity of maize under irrigation in Kakhovka region – 12,5 t/he, Chaplynka region – 13,7 t/he (maximum performance according to the weather station Nova Kakhovka was obtained in 2003 (medium dry year) – 18,0 t/he, in 2004 (wet year) – 17,0 t/he and according to the weather station Askania Nova in 2004 (wet year) – 19,2 t/he, in 2006 (average year) – 17,7 t/he), without irrigation in Kakhovka region – 3,9 t/he and in Chaplynka region –3,4 t/he. With it, the rate of actual yield under irrigation of many farms in the Kherson region in average is 5,8 t/he, with it, the rate of actual yield under irrigation of many farms of the Kherson district in average is 5,8 t/he. Well known, that a soil fertility influences on the formation of yields, especially without irrigation. Also, total amount of precipitation during growing season it is not so important than its coming in time on important phase of plant development: young growth, flowering and full ripeness. The analysis of inside seasonal distribution of rainfall showed that under favorable climatic conditions in 2005 without irrigation we got high simulated yield – 6,3 t/he. And in medium-dry 2007 and in wet 2010 recorded a low simulated yield (2007 – 8,5 t/he, in 2010 – 8,6 t/he). This is because in flowering stage, when a rain washed away pollen, didn't happened a complete fertilization of plants, this is also leads to lower yields (future 1).

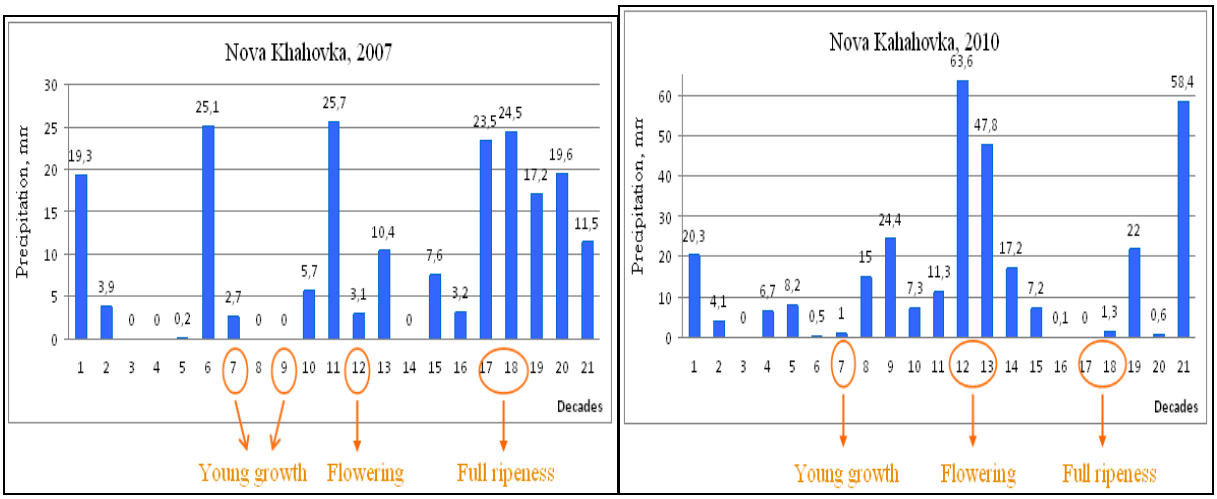

Fig.1. Inside seasonal distribution of rainfall, weather station Nova Kakhovka

Today, in Kherson district the amount of maize yield fixed even till 20,0 t/he and more, that due to the using of new and more productive hybrids. But, unfortunately, not every farms are able to achieve such performance level (statistical average yield for the 2000-2013 biennium in the region is 5,9 tons/he [6, 12]). Also, high yield of crops is obtained under favorable conditions of some years, on productive soils and with intensive technologies in irrigated agriculture. Therefore, the work purpose is to evaluate the potential productivity of lands on the pilot territory, if every farm will reach a simulated level, that is calculated for the specific soil and climatic conditions of the past 14 years for each typological zones. To have such vision in the world practice people use the methods of scenario [3, 9]. By the most accepted definition, scenario is not a forecasting, it is an alternative vision of the future functioning of complex social, natural and technical systems. In our work, according to a methodology [9], have been developed the next types of water and land use scenarios [7]: *Scenario № 1 «Business as usual» (current stage)*

takes into account an existing conditions of water an land use, climate changes, that are occurred in the last 20 years and also potential of agriculture under natural conditions and modern farming technologies; *Scenario № 2 «Restoration»* takes into account the probable climate changes (warming trend: increasing of annual air temperature on 1 °C [2, 4], provides the restoration of irrigated territories till the level that was at large-scale use time in the past, also considers a current potential level of agricultural lands; *Scenario № 3 «Modernization»* also takes into account probable climate changes and provides the restoration of irrigated lands, but on limited area with favorable environmental conditions under water and energy saving technologies (technical solutions that provide till 30 % saving of water and energy resources) with corresponding data of potential of agricultural lands.

Accordint to created scenarios were involved a 30,2 % of the pilot area. This area is occupied by grain maize according to statistics in 2013 [12]. By results of potential level of land productivity defined, the largest gross of grain maize (with and without irrigation) 1023,1 ths. tons can be achieved by scenario № 2 on the 209,8 ths. he. The lowest land productivity (697,6 ths. tons) by scenario № 1 on 124,3 ths. he. If to compare it to the current practice in irrigated agriculture, by obtaining low yields cultural capacity is 435,9 ths. tons, which is on 37,5 % less than by scenario № 1 on the same area of cultivation. By scenario № 3 on the territory 206,6 ths. he the crop production amounted till 870,7 ths. tons. The simulation results of potential level of land productivity and proposed scenario method, that obtained under conditions of the pilot area, can be distributed for other areas of Steppe zone in Ukraine in plans of strategy about restoration and development of irrigation.

In the work also completed the feasibility study for variant of methods and techniques of irrigation (front and circular action sprinkler, drip irrigation) for medium-dry years conditions. Data analysis of three types of irrigation use showed that the minimum income (69,6 ths. UAN/he) and profit (13,5 ths. UAN/he) from crops sale, and in some cases losses, with an average amount all costs - 55,9 ths. UAN/he (cultivation, irrigation and overhead costs) obtained under current natural-economic conditions of irrigation use and actual low levels of yields. Given the conditions of simulated scenarios of water and land use № 1 & 2 the most revenue (88,7 ths. UAN/he) with an average profit (32,8-30,3 ths. UAN/he) is received by reaching the potential level yields, only scenario № 2 is observed the maximum values of total expenses (58,4 ths. UAN/he) from the increased irrigated norms. By scenario № 3 with resource-saving technologies till 30%, in contrast to the current natural-economic conditions and other water and land use scenarios, fixed a minimum amount of total expenses (53,2 ths. UAN/he) and the minimum income (74,6 ths. UAN/he) from plant products sale and despite the fact that profit was 25,6 ths. UAN/he, the scenario № 3 is economically viable.

By analysis of different irrigation methods is revealed that in 15 years lands of drip irrigation are rapidly increasing. So in 2000 on the Southern Part of Ukraine drip irrigation amounted to 1,4 % of the total area of irrigation, and in 2014 - was risen till 15,6 %. Assumingly, that this type of irrigation will continue to develop through the its resource efficiency, in simulating water and land use scenarios a 30 % of drip irrigation are suggested in our work. In table № 1 are showed the comparative economic indicators assessment of variants of methods and techniques of irrigation in current natural-economic conditions and conditions of water and land use scenarios for years of 75 % natural moisturizing. All the economic calculations were performed by existing 2014 levels according to the expenditures newsletter of independent Public Advisory Council of the price situation in the agricultural market.

1. The assessment of variants of methods and techniques of irrigation in current natural-economic conditions and conditions of water and land use scenarios for years of 75 % natural moisturizing.

n/n	Square and variants of methods and techniques of irrigation	Profit, expenses and payback period	Current stage	Water and land use scenarios		
				№ 1	№ 2	№ 3
		Agricultural lands, ths. he	124,3	124,3	209,8	206,6
Variant № 1	100 % sprinkler of circular action	Profit, mln uan.	227,6	1016,6	1607,9	1195,2
		Spending, mln uan.	4500,0	4500,0	7590,0	7480,0
		Payback period, years	19,8	4,4	4,7	6,3
Variant № 2	100 % sprinkler of front action	Profit, mln uan.	177,8	966,8	1517,1	1119,9
		Spending, mln uan.	4860,0	4860,0	8210,0	8080,0
		Payback period, years	27,3	5,0	5,4	7,2
Variant № 3	70 % sprinkler of circular action and 30 % drip irrigation	Profit, mln uan.	476,2	1101,9	1657,7	1230,0
		Spending, mln uan.	4460,0	4460,0	7550,0	7430,0
		Payback period, years	9,4	4,0	4,6	6,0
Variant № 4	70 % sprinkler of circular action and 30 % drip irrigation on irrigation system	Profit, mln uan.	464,1	1089,8	1655,7	1128,3
		Spending, mln uan.	5800,0	5800,0	9140,0	9000,0
		Payback period, years	12,5	5,3	5,5	7,3

With feasibility study of various methods and techniques of irrigation for different water and land use conditions, in the work is offered the most cost-effective variant - № 3. According to its conditions is stipulated a combined using of circular sprinkler irrigation on 70 % lands and 30 % of lands with drip irrigation with individual modules of farm irrigation systems. By results of calculation determined that the introduction of variant № 3 of method and technique of irrigation with of resource-saving technologies of water and land use scenario № 3 are ensured a minimal cost to implementation of plans of restoration for irrigation and highest incomes with short payback of investments. The final conclusion about effectiveness of a technical solution can be made only after settlement of all other expenses and gains that can be achieved under different conditions irrigation use.

Conclusions.

The plans of irrigation development and agricultural production must be based on the results of current potential assessment of agricultural lands according to a simulated conditions of water and land use scenarios. In the work such assessment was done by simulation of water and land use scenarios on the example of maize - the scenario № 1 – 697,6 ths. tons, № 2 - 1023,1 ths. tons, № 3 – 870,7 ths. tons. Those scripts allowed quantifying the potential level of land productivity according to different influences (amount of irrigated areas, intensive and resource-saving irrigation, climate changes). The strategic planning of restoration development of irrigation, that based on simulated scenario, shows that the most perspective and sustainable scenario is № 3 «Modernization» - modernization of irrigation system, which

involves reducing environmental risks and costs of water and electricity per 1 ton of yield. And combined a sprinkler and drip irrigation variant that provides the highest profits with short payback of investments.

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