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Irrigation as the principal element of modern agrotechnologies in conditions of South Steppe of Ukraine

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The purpose. To justify scientifically directions of application of irrigation in modern crop production technologies in rainless conditions of South Steppe of Ukraine. **Methods**. Analysis, synthesis, generalization. **Results.** In conditions of climate fluctuation it is necessary to use in irrigation farming of Ukraine the intensive crop production technologies based on use of innovative methods with optimization of different methods of showering and regimes of irrigation, fertilizer systems, treatment and protection of plants. Structure of sown area and crop rotations on irrigated lands of Ukraine for intelligent use of irrigated lands and avoidance of negative impact of external factors of natural and anthropogenic character is offered. Methodological and methodical approaches are developed on the basis of integral criterion of irrigated lands for their intelligent use, avoidance of degradation processes, protection and reproduction of fertility. Resources saving techniques are improved of cultivation of different crops on biological properties with observance of project normative expenditures worked out by scientists of Institute of irrigation farming and other scientific institutes of NAAS. Scientific approaches on state-private partnership in guidance system of water resources are developed, and instruments of state support and regulation of entrepreneurial business in the field of irrigation farming are specified. **Conclusions.** The major on immediate prospects will be problems of decreasing all sorts of resource losses by irrigation and other elements of agrotechnologies in conditions of regional climate fluctuations. For this purpose it is necessary to develop new scientific approaches on application of innovative techniques of artificial irrigation on the basis of minimization of discharge of water, energy, work and means, setting of irrigation water, fertilizers, pesticides and biological preparations, taking into account location of root system of crops for determination of optimum doses of watering, use of solar energy for alternative power supplies and so forth.

Keywords: *climate, drought, crop rotation, soil cultivation, fertilizers, resources saving methods of irrigation, economic efficiency.*

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Introduction. On the basis of the modeling of climate changes processes, conducted by the international team of the scientists of the Cambridge group under the aegis of the FAO UNO, further rise in the air temperature in the range from 2 to 6^{o}C in the period until 2100 is predicted [1]. This increase in the temperature and CO_2 concentration in the air will have a direct impact on the biosphere of the Earth, including the productivity of the agro-industrial complex, the yield and quality of products of crops. Negative climate changes in the nearest future include the rise in the air temperature, strengthening of the drought effects, reduction of snow cover, disturbance of the uniformity of precipitation distribution, which in complex will lead to the intensification of erosion processes and soils degradation.

Increasing drought of the climate has caused the need to change approaches to the formation of agricultural systems, especially in Southern Steppe of Ukraine. For the last 45 years, the amount of effective and positive temperatures during the vegetation period in this region has increased almost to 700^{o}C that has prolonged its duration by 12-14 days [2]. At the same time, it should be noted that the productivity of the plant sector, as well as of the agriculture on the whole, strongly depends on the impact of climatic factors [3].

Irrigation in the conditions of a severe deficit of natural moisture is one of the main factors of countering the negative effects of global warming and improving the productivity of the crop industry. Optimum interaction with other constituents of agriculture and complex mechanization favors to the intensive use of heat, light, nutrients, moisture by plants that in the complex provides an effective use of land resources, promotes obtaining of high and sustainable yields of different by biological features and genetic potential crops [4].

During the twentieth century, irrigation has become widespread in the world, currently more than 345 million hectares are irrigated on the planet, which is 21% of the total arable land, on which it is produced more than 40% of all agricultural products, that is because the productivity of one irrigated hectare more than twice exceeds the yield of plant products of non-irrigated area. High efficiency of artificial humidification led to the solving the food security of mankind, as the rapid growth of irrigated lands has led to a significant reduction in the global food prices index from 2.2% in 1971-1980 years to 0.8% – in 2000-2005 [5].

At the moment, due to the global climate change, which manifests itself in the increase of air temperatures, reduction of its relative humidity, reduction of the amount and disturbance of the uniformity of precipitation distribution, increase in the deficit of qualitative irrigation water makes for the necessity to use new methodological approaches to the organization of artificial humidification at both regional and micro-local levels [6].

In many countries in the world, small farms do not have enough money, time, energy or water, because existing irrigation technologies are extremely resource consumptive. Soil tillage, fertilization, sowing, plant care, harvesting requires large labor costs and time, diesel pumps need fuel, electric – connection to the networks and electricity, but sometimes water does not come to the root zone of plants, and, for example, evaporates into the air (at watering by sprinkler irrigation), runs off the fields (at surface way of watering), moves into deep layers of soil and becomes inaccessible (watering by flooding) [7].

Thus, intensive cultivation technologies make for the need to use large amounts of resources to obtain optimum levels of yields. Therefore, important scientific and practical significance has the application of innovative approaches to the formation of systems of agriculture on irrigated lands, which are based on the principles of water-and resource-saving, development of the norms for consumption of irrigation water, fertilizers, pesticides and biopreparations, considering the location of the root system of crops, the use of alternative energy sources, etc. [8].

Aim of the study. Scientific substantiation of directions for irrigation use in modern crops cultivation technologies in the arid conditions of Southern Steppe of Ukraine.

Materials and methods of the study. The study was carried out using modern methods of experimental work in agronomy and irrigated agriculture [9]. Results of field experiments with different crops of domestic breeding, which were conducted accordingly to the generally accepted methodology, were used to determine statistical ties [10]. To avoid the effect of limiting factors of cultivation technology on the results of statistical processing the yields obtained at the optimal irrigation regimes and mineral fertilization backgrounds were evaluated.

Results of the study. Worldwide, agricultural water consumption is about 70% and energy consumption is about 30%. Therefore, the questions of the reduction of costs of both irrigation water and energy during watering are strategic ones. Realizing that many agricultural producers are limited by resource supply, the scientists of agrarian science should offer a set of measures to save and minimize water consumption, energy, labor and resources through the development and testing of the latest technologies, existing on the considering the costs of these four resources, which may have an important value and increase the economic efficiency of irrigated agriculture [11].

Drip irrigation in 2-3 times decreases the cost of irrigation water per unit of sowing area, increases yields and improves the quality of plant products. However, the main advantage of this method of artificial humidification is saving resources and increasing their payback by the unit of additional yield. Drip irrigation due to its numerous advantages has been used for the first time over 100 years, but until nowadays it requires improvement and increase of its resource-saving direction. Therefore, resource-saving technologies of artificial humidification should be adapted to the unique features of each enterprise and region.

Prospective ways for solving the problems of irrigated agriculture concerning resource conservation and increase of economic efficiency are the use of micro-irrigation and pumps working on solar power.

To optimize irrigation and to reduce the expenditures of irrigation water and energy resources, it is necessary to develop and apply innovative systems of artificial humidification with the maximum simplification and low cost. Thus, the important value has the consideration of local irrigation conditions and irrigation area for the manufacturing of pumps. In recent years, wide distribution was obtained by the pumps with a power of 40-200 Watts, which are used for the irrigation of small fields with an area of 1000 to 5000 m^2. In such conditions, it is possible to use solar batteries for power supply of such pumps and to compensate the expenditures for irrigation during one or two seasons of crops cultivation.

Crops cultivation is connected with the action and interaction of many factors, that is testified by the influence of natural and anthropogenic conditions. At the level of each farm to improve the environmental friendliness of agrotechnical and melioration measures and agricultural methods, it is necessary to assess their impact on the soils and agro-ecosystems. In the South of Ukraine, the most effective measure of soil water regime improvement is artificial humidification, which allows to significantly increase the productivity of agriculture. Perennial field researches of the Institute of Irrigated Agriculture of the National Academy of Agrarian Sciences of Ukraine and other scientific institutions have proved that due to the artificial humidification it is possible to create favorable conditions for realization of potential possibilities of varieties and hybrids, and provide a substantial increase in gross production volumes per the unit of sowing area.

Increasing the efficiency of scientific research and competitiveness of scientific developments in the field of irrigated agriculture in southern region of Ukraine is a significant lever of stabilization of agricultural production in the arid climate and one of the priority directions of the state policy. The Institute of Irrigated Agriculture of NAAS has been developing and constantly improving the systems of irrigated agriculture in the areas of the Steppe zone, which allow to receive the 3-5 times higher yields in comparison to non-irrigated conditions, and irrigation regimes are oriented to the biological and genetic features of modern varieties and hybrids saving 15-40% of irrigation water actually without the loss of yields.

Theoretical developments on the optimization of soil processes on the irrigated lands substantiate the scientific bases of rational and environmentally safe application of fertilizers and ameliorants. Wide distribution obtained the use of new resource-saving systems of crops fertilization, which every year are introduced in the areas of Kherson, Mykolaiv, Dnipropetrovsk regions on the area of 50 thousand ha and provided the reduction of expenditures for mineral fertilizers by 24-72%, compared to the accepted norms. The developments of the Institute were included as a constituent part in the “Prospective plan for preservation and increase of fertility of soils in Kherson region”.

Introduction of the developed by the Institute of Irrigated Agriculture of NAAS “Methods for determination of the payback of irrigation water and reimbursement for its supply” will increase the efficiency of the water supply complex and irrigated agriculture in southern region on the whole, providing the possibility of more rational allocation of funds.

The development of the Institute consists of scientific and technical base of agriculture conduction on the irrigated lands in southern region. In short crop rotations a system of soil-protective energy-saving soil tillage, which provides saving of fuel-lubricants materials (by 20%) under a decrease in the energy intensity of the process (by 40%), became widespread in the region. The improved at the Institute crop cultivation technologies is being implemented on the irrigated lands in Kherson, Mykolaiv, Odesa and Dnipropetrovsk regions on the area (thousand hectares): winter wheat – 150, soybean – 35, vegetable crops – 25. Water-saving regimes of crops irrigation, which ensure saving of irrigation water and energy resources and obtaining 4.5-5.5 million UAH of pure profit, are used in the farms of Kherson, Mykolaiv, Dnipropetrovsk, Zaporizhzhya regions on the area of 300 thousand ha.

In the field experiments of the Institute of Irrigated Agriculture it was established that due to the best indexes of the bulk density, porosity and water permeability, the content of moisture at the time of the spring regrowth of winter crops and at the appearance of spring crops sprouts at different-depth systems of plowing and plowless tillage were 3.5-7% higher than at the shallow single-depth system. Water consumption for the formation of one ton of products in all crop rotations was the lowest at the different-depth plowing and ranged from 723 m^3/t in crop rotation with 75% share of cereals up to 973 m^3/t under the reduction of the cereals share to 50% and up to 1100 m^3/t – under the reduction to 25%. This pattern is also observed at the systems of the different-depth and single-depth shallow plowless tillage with the decrease, respectively, by 5-10% and 50-60%.

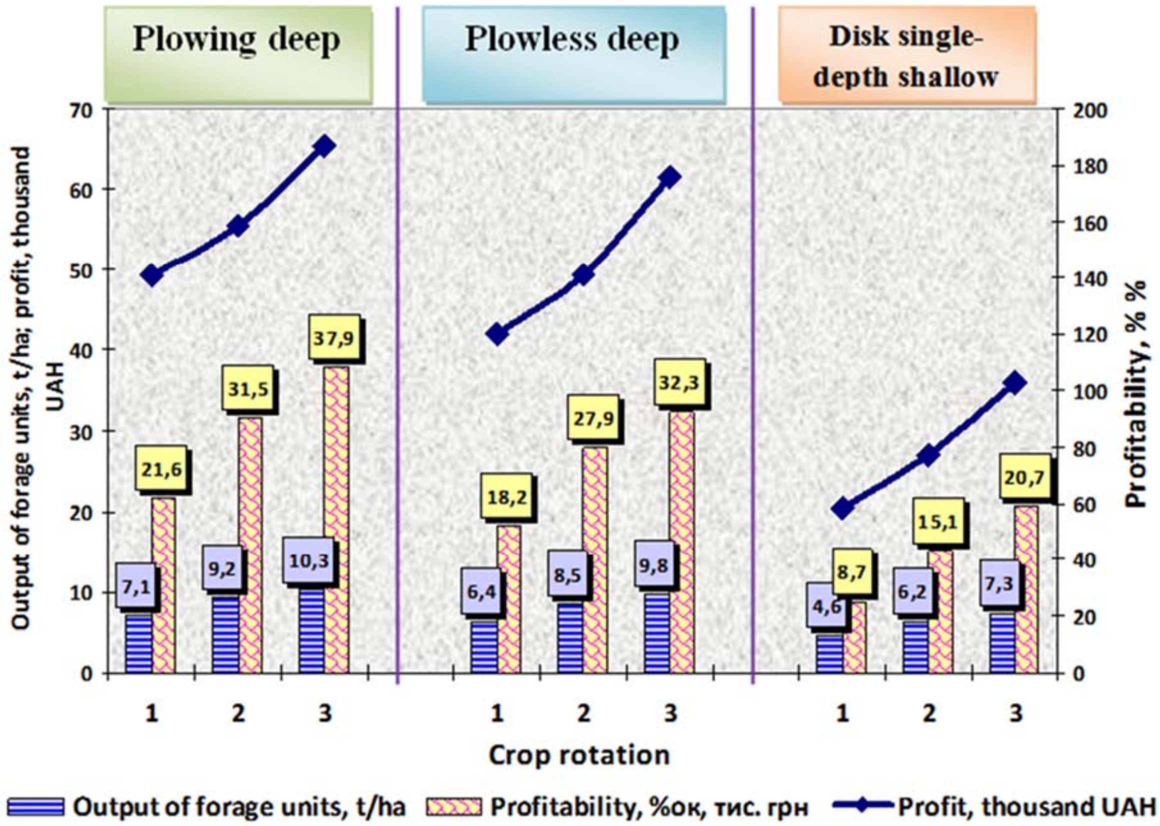
More favorable conditions for the accumulation of nutrients in the soil layer of 0-40 cm were created at the beginning of the spring vegetation of crops in the crop rotation with 75% share of cereals and on the background of the different depth plowing basic tillage.

Replacement of plowing with the plowless deep basic tillage led to the decrease of the content of nitrates, mobile phosphorus and exchangeable potassium, respectively, by 10, 17 and 8%, and at the use of shallow plowless loosening these indexes were lower, respectively, by 27, 23 and 13%. This pattern was observed in the crop rotation No. 1 with 25 and No. 2 with 50% share of cereals, at the same time, the indexes of the nutrients content were significantly lower.

The highest yield of crops and crop rotation productivity was provided by the crop rotation No. 3 with 75% share of cereals and 25% share of industrial crops at the different-depth plowing tillage, where its indexes averaged to 10.3 t/ha, with a profit of 37.9 thousand UAH and profitability level of 187% (Fig.).

At the same time, a single-depth shallow one provided the level of profitability, which decreased to 103%. In the first and second crop rotations, the profit and profitability level were significantly lower, at the same time, the regularity in regard to the methods and depths of the basic tillage saved.

In the field researches in the direction of the optimization of cultivation technology of new corn hybrids of different FAO groups at different ways of irrigation and quality of irrigation water, the level of mineralization, ion-salt composition of irrigation water and its irrigational assessment according to the DSTU-2730-2015 were made. Basic information on the economic efficiency of the complex action of new hybrids of corn, different ways of irrigation in the conditions of the Ingulets and Kakhovka irrigation systems was obtained.



Productivity and cost-effectiveness indexes of the crop rotation functioning under different soil tillage systems

It was found that under the watering with water of the Class II from the Ingulets irrigation system, the yield of corn hybrids decreased by 5-10%, compared to the results of the studies obtained in the Kakhovka irrigated array (Table).

The highest grain yield at sprinkler overhead irrigation of 14.1-18.8 t/ha was formed by the hybrids with FAO 380-430 Azov and Ararat, and at drip irrigation the absolute advantage was of the hybrid Aral, the grain yield of which increased to 18.7-19.0 t/ha.

One of the main factors of the intensification of production in irrigated agriculture is plant breeding developments. The Institute of Irrigated Agriculture creates the newest varieties and hybrids with genetically predetermined adaptability to the conditions of irrigation. Over 70 varieties and hybrids of winter wheat, soybean, corn, alfalfa, tomato and other crops have been created.

The grain yield of corn hybrids at different ways of irrigation and irrigation regimes, t/ha (average for 2016-2018)

No.	Hybrid	FAO	Irrigation with DDA 100MA, Ingulets irrigation array, TAW at 80% FC	Drip irrigation, Ingulets irrigation array, TAW at 85% FC	Drip irrigation, Kakhovka irrigation array, TAW at 85% FC	Irrigation with Zimmatic, Kakhovka irrigation array, TAW at 80% FC
1	DN Pivikha	190	9.75	10.10	10.76	10.57
2	Oberih	190	10.61	11.00	12.10	11.54
3	Hawtyn	250	12.61	12.29	13.41	13.97
4	Galateya	250	12.21	11.91	13.46	12.71
5	Korund	280	12.38	12.64	12.54	12.42
6	Rostok	300	12.93	14.81	15.65	12.85
7	Zbruch	350	12.77	14.87	15.20	12.81
8	Vizyr	350	10.61	11.43	11.72	11.48
9	Kakhovskyi	350	11.23	13.72	13.28	11.37
10	Azov	380	14.09	14.25	15.34	14.57
11	Rava	420	14.65	15.81	16.27	14.38
12	Arabat	430	14.30	18.71	18.95	14.83
LSD_{05}			0.37	0.56	0.42	0.44

Winter wheat varieties have a potential yield of 8-11 t/ha of grain, and high adaptive ability. New alfalfa varieties combine high potentials of forage, seed and nitrogen-fixing productivity with wide adaptive abilities to the biotic and abiotic conditions of the environment, which can accumulate in the soil up to 0.27 t/ha of biological nitrogen. High-productive soybean varieties of different ripeness groups are created, with a yield level of 3.7-5.6 t/ha of seeds, high protein content of 39-42% and fat content of 20-23%. Besides, new varieties and hybrids have the advantage of resistance to diseases and lodging.

The efficiency of agricultural technologies on the irrigated lands is confirmed by their large-scale introduction. In the South of Ukraine, the developed soil tillage system is applied on the area of 200-215 thousand ha. Resource-saving system of fertilization of crops using optimal parameters of the content of nutrients in the soil is implemented on the area of 57.5 thousand ha. At the same time, resource saving on average amounted to 150 UAH/ha. In Kherson region, the cultivation technology of tomato with application in the technological process of own varieties is introduced. It has provided the maximum fruit yield of 115 t/ha, with the dry matter content in fruit up to 7%. The volume of introduction – 1600-2500 ha with the prospects of further its expansion to 10 thousand hectares.

Conclusions

So, in the conditions of climate change in the irrigated agriculture of Ukraine it is necessary to use intensive technologies of crops cultivation, which are based on the use of innovative principles with the optimization of different methods of irrigation and irrigation regimes, fertilization systems, tillage and plant protection. The structure of acreage and crop rotations on the irrigated lands of Ukraine for rational use of the irrigated lands and prevention of the negative influence of external factors of natural and anthropogenic nature are proposed.

The methodological and methodical approaches to the integrated estimation of the irrigated lands for their rational use, prevention of development of the degradation processes, protection and recovery of soil fertility are developed. The resource-saving cultivation technologies of different by the biological characteristics in accordance with the project normative expenses, which are specified by the scientists of the Institute of Irrigated Agriculture and other scientific institutions of NAAS, are improved, scientific approaches to the state-private partnership in the system and management of water resources are proposed, the instruments of the state support and regulation of entrepreneurial activity in the field of irrigated agriculture are determined.

The issues of the reduction of all types of resource losses at irrigation and other elements of agrotechnologies in the conditions of global climate change will be of a importance. It is required to work out new scientific approaches regarding the application of innovative technologies of drip irrigation on the basis of minimization of water, energy, labor and money expenditures, regulation of irrigation water, fertilizers, pesticides and biopreparations, considering the location of the root system of crops to determine the optimal irrigation norms, use of solar energy as an alternative energy source, etc.

References

1. Balyuk, S. A., Romashchenko, M. I., & Stashuk, V. A. (Eds.). (2009). *Naukovi osnovy okhorony ta ratsionalnoho vykorystannia zroshuvanykh zemel* [Scientific bases of protection and rational use of irrigated land]. Kyiv: Agrarian science. [In Ukrainian].

2. Snihovyi, V. S. (2003). Problemy zemlerobstva y efektyvnist suchasnoho vyrobnytstva [The problems of agriculture and the efficiency of modern production]. *Tavrian Scientific Messenger*, *27,* 29-33. [In Ukrainian].

3. Babych, A. O. (1996). *Svitovi zemelni, prodovolchii kormovi resursy* [The world land, food and forage resources]. Kyiv: Agrarian science. [In Ukrainian].

4. Silva, Z. G., Nvaze, K. F., & Kazyn, E. (2016). *Dostizhenie nulevogo goloda. Kriticheskaya rol investitsiy v sotsialnuyu zashchitu i selskoe khozyaystvo* [Reaching a zero hunger. A critical role of the investments in social protection and agriculture]. (pp. 12-14). Rome, FAO UNO. [In Russian].

5. Gathala, M. K., Timsina, J., Islam, Md. S. et al. (2014). Conservation agriculture based tillage and crop establishment options can maintain farmers' yields and increase profits in South Asia's rice-maize systems. *Evidence from Bangladesh. Field Crops Research*, *85-98.* https://doi.org/10.1016/j.fcr.2014.12.003.

6. Asfaw, S., & Maggio, G. (2016). *Gender integration into climate-smart agriculture. Tools for data collection and analysis for policy and research. Food and Agriculture Organization of the United Nations*. Rome.

7. McCarthy N. (2011). *Understanding agricultural households' adaptation to climate change and implications for mitigation: land management and investment options. Integrated Surveys on Agriculture*. (pp. 42-47). Washington D.C., USA: LEAD Analytics Inc.

8. Snegovoy, V. S., & Havrylisha, A. O. (1989). *Oroshenie: ot drevnego iskusstva do sovremennoy nauki* [Irrigation: from the ancient art to the modern science]. Chisinau: Schtypntsa. [In Russian].

9. Netis, I. T. (1994). Zmina klimatu v zoni zroshennia [Climate change in the zone of irrigation]. *Irrigated Agriculture*, *39,* 7-12. [In Ukrainian].

10. Snihovyi, V. S., Zhuykov, G. Y., & Dymov, O. M. (2003). Ekonomichni vazheli ekoloho-bezpechnoho vedennia zemlerobstva na zroshuvanykh zemliakh Pivdennoho Stepu [Economic levers of ecology-safe farming on the irrigated lands of Southern Steppe]. *Agroecological Magazine*. *Kyiv,* 32-37. [In Ukrainian].

11. Fischer, R. A., Byerlee, D., & Edmeades, G. O. (2014). Crop yields and global food security: Will yield increase continue to feed the world? *Australian Centre for International Agricultural Research,* 158, 52-59. https://doi.org/10.1007/s12571-014-0392-y.