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# Prospects for the effective use of irrigated lands in Karakalpakstan in conditions of water resource scarcity

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**Abstract.** Present the results of many years of development on the effective use of irrigated arable land and water resources in conditions of water shortage. At the same time, a decrease in rice content to 40% and the saturation of the crop rotation wedge with other upland grain crops leads to the gradual use of arable land up to 120% and the grain size increases to 80% relative to the opposite scheme. Reducing rice content by up to 40% on medium loamy soils, with the rice irrigation rate recommended for this zone, allows saving about 25-27% of irrigation water. The use of the recommended technology ensures an increase in rice yield within the range of 11.2 centners, winter wheat - 11.3 centners/ha. The sorghum crop additionally introduced into the scheme provided 66.4 c/ha of yield. Thanks to drip irrigation, when re-seeding after winter wheat, 24.0 tons/ha of potato yield was obtained, when using conventional technology 12.5 tons/ha were obtained. At the same time, the savings in irrigation water amounted to 50-55%, in addition, the use of expensive mineral fertilizers was reduced by 35-40% and plant protection products by 25-30%. Thus, in the conditions of the Republic of Karakalpakstan, the introduction of a drip irrigation system that supplies plants in accordance with their water consumption is a relevant and modern approach to the issues of saving natural resources, creating optimal water and nutrient regimes in the root layer of the soil, obtaining an early and high-quality harvest of agricultural crops, automation of irrigation processes, preservation of soil fertility and mitigation of the environmental situation of the region.

## 1 Introduction

The Republic of Karakalpakstan, while having considerable agricultural potential within Uzbekistan, struggles with low crop yields due to limited water resources. To address this,

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improving agricultural efficiency through the use of high-yielding crop varieties and advanced agricultural technologies is crucial. This approach will help maximize the use of the region's land and water resources, meeting the high market demand for these crops.

The increasing shortage of water resources and the associated increase in summer (abnormal) temperatures dictates an even greater increase in the aridity of the vast territories of the republic and a decrease in the productivity of both natural and artificial phytocenoses. Therefore, finding and developing ways to rationalize the use of natural factors and technology for cultivating saturated crops in rice crop rotation is a pressing issue of today.

Therefore, the solution to this problem consisted of 2 stages: the first stage was the optimization of rice sown areas based on their reduction, the second stage was the selection of saturating crops and the development of their resource-saving cultivation technology.

A reduction in rice acreage, at first glance, will inevitably entail a decrease in the economic efficiency of the industry. Nevertheless, these losses can be offset by the widespread adoption of new environmentally adaptable varieties that are well-suited to adverse environmental conditions and possess high technological qualities. Another way to stabilize the economy of the industry is to compact (saturate) the freed-up rice fields of crop rotation with promising grain crops, ensuring a grain balance from the entire complex.

Crop rotations, as a rational form of using irrigated lands, should become the basis for specialization and concentration of crop and livestock production on farms, regardless of the form of ownership.

More complete use of natural factors due to the compaction of crop rotations and the introduction of additional (saturating) crops into them is one of the decisive prerequisites for increasing the productivity of arable land in conditions of scarcity of water resources.

Advanced farming practices indicate that the ideal inclusion of intermediate crops in crop rotations is influenced by the type of crop rotation, farm specialization, as well as soil and climate conditions. An important condition for the successful cultivation of saturating crops is an accurate accounting of their area, yield and biological compatibility with the main ones. In crop rotations, the structure of sown areas is closely linked to both natural resources and the agricultural production program.

Therefore, all agricultural research must focus on food security and nutrition, as well as adaptation to and mitigation of climate change.

In the conditions of the Republic of Karakalpakstan, irrigation is the main factor in obtaining and increasing crop yields. In order to increase efficiency, it is necessary to modernize the irrigation regime, watering techniques, etc. irrigation methods. The main factor in this case is the creation of promising water-saving technologies with higher efficiency in the extreme conditions of the region, which could save reserve resources and increase productivity.

Rational use of available water resources is the main task in the republic, since it has an arid, dry climate. 20% of the water used is formed on the territory of Uzbekistan, the remaining 80% on the transboundary rivers Amudarya and Syrdarya. Due to the fact that the bulk of water resources are formed outside the territory of the republic, the main task is the rational use of water, the use of the most effective methods of irrigation.

In this regard, the goal of this work was to improve the use of land and water resources and increase their productivity in conditions of water scarcity.

The scientific novelty lies in an integrated approach, including innovative reclamation measures in the development of scientifically based schemes for the placement of agricultural crops and the modernization of irrigation methods in conditions of water scarcity.

## 2 Research methodology

Scientific research in this area was conducted at the experimental farm of the Research and Production Association of Grain and Rice in the Republic of Karakalpakstan. The farm's activities include propagating region-specific and newly developed varieties of rice, grains, and legumes, as well as advancing modern resource-efficient cultivation technologies.

With the current advancements in agronomic sciences, agriculture can be described as a field focused on developing methods to optimize the use of irrigated arable land and enhance soil fertility to boost crop yields.

Agrotechnical measures were carried out in accordance with generally accepted recommendations for this zone. The experiments were carried out according to the method proposed by B.A. Dospehov (1985). The area of the experimental plots is 50-100 m2, 4 times replicated.

The soil conditions of the experimental plots did not differ significantly. The soils consist of gray meadow-alluvial types. Nutrient levels at the start of the growing season varied, but deficiencies were addressed through the application of mineral fertilizers. The salt content in the measured soil layer is average, and the groundwater level ranged from 2.5 to 3.0 meters.

Irrigation water in the experimental areas was used from the main canal P2 with a salinity of 1.5-2.0 g/l, pH-7, 0 which fully complied with the conditions.

The climate of the Republic of Karakalpakstan is marked by sharp continentality, significant annual temperature variations, long summers, consistently clear weather, and pronounced daily temperature swings with very dry air. In the northern part of the republic, the thermal period with temperatures above 0°C lasts for 240 days, while it extends to nearly 300 days in the south. Precipitation is minimal, ranging from 80 to 100 mm, and mainly occurs in winter and spring, with the highest amounts in March and April. Snow cover is unstable. During the research period on experimental plots, the water-physical properties of the soil were assessed, irrigation water quality was monitored, and observations were made on plant growth and development in the crop rotation wedge, with biological yields also recorded. All studies were carried out according to generally accepted methods for this zone.

## 3 Results discussion

Under the existing 7-field rice crop rotation scheme, rice occupied 57.1%, alfalfa 28.6% and fallow occupied 14.3% of the area. For the effective use of irrigated arable land in conditions of scarce water resources, we proposed a 5-field crop rotation scheme, in which the area under rice was reduced to 40%, winter cereals occupied 30%, sorghum - 10, sunflower - 20 and alfalfa - 20%. The saturation of the crop rotation wedge was 120%.

The results of the study showed that increasing the utilization rate of irrigated arable land by saturating the crop rotation wedge with other upland grain crops has a beneficial effect on increasing the productivity of the entire complex. At the same time, the grain content of the crop rotation wedge increases to 80%.

Reducing rice content to 40% on medium loamy soils, with the rice irrigation rate recommended for this zone, allows saving about 25-27% of irrigation water, due to which it is possible to cultivate an additional 300-325 hectares of dry grain crops. It should be noted that under the conditions of rice crop rotation, the consumption of the irrigation water norm for saturating grain crops is within 1200 m3/ha.

The use of the recommended technology ensured an increase in rice yield within 11.2, winter wheat - 11.3 c/ha. The sorghum crop additionally introduced into the scheme provided 66.4 c/ha of yield.

Intensive use of arable land with the inclusion of intermediate and cover crops in crop rotation significantly enriches the soil with plant residues, including roots and unused above-ground biomass.

The plant mass of crops plowed into the soil has a high content of nitrogen, phosphorus, potassium and other nutrients. It is evenly distributed over the soil profile and is easily microbiologically decomposed, releasing a large amount of nutrients (6).

Therefore, let us examine how the accumulation of underground biomass changes in rice crop rotation.

**Table 1.** The pattern of underground dry biomass accumulation in rice crop rotation plants (2003-2005)

| № | Culture | Horizon, cm | Underground mass, t/ha |
|---|---|---|---|
| 1 | Alfalfa 2 years standing | 0-30 | 7.22 |
| 2 | Rice | 0-30 | 8.11 |
| 3 | Winter wheat | 0-30 | 7.98 |
| 4 | Sorghum | 0-30 | 3.94 |

As the data presented in the table show, the formation of underground dry mass by plants has a great influence on the accumulation of organic matter in the arable horizon. Improving the agrophysical and agrochemical properties of the soil creates favorable conditions for crop growth within a crop rotation system. Our research indicates that over 27.19 tons per hectare of organic matter accumulate in the arable horizon after one crop rotation. By incorporating upland grain crops and reducing the proportion of rice, the crop rotation system enhances soil properties, leading to a 35-40% reduction in the need for expensive mineral fertilizers and a 30-35% reduction in pesticide use compared to current practices. This approach also positively impacts the reclamation of irrigated lands and boosts overall productivity.

Currently, many arable lands in the republic are experiencing a gradual decline in soil physical properties due to factors such as heavy agricultural machinery, reduced humus content, and erosion. Humus content and its composition are crucial in determining soil physical properties. Without sufficient fresh organic matter from fertilizers and plant residues, soil structure and its physical properties deteriorate. Compaction, which is particularly problematic in irrigated agriculture, reduces soil porosity and hampers the uptake of nitrogen, phosphorus, and potassium, as well as soil nitrification. Therefore, it is essential to examine how the physical properties of soils change based on the crops cultivated in a rotation system (see Table 2)

**Table 2.** Volumetric mass of soil depending on predecessors, g/cm$^3$ (2003-2005)

| Horizont, sm | After rice | After alfalfa 2 years of standing | Before sowing winter wheat | After sorghum |
|---|---|---|---|---|
| 0-10 | 1.14 | 1.28 | 0.99 | 1.08 |
| 10-20 | 1.28 | 1.32 | 1.08 | 1.17 |
| 20-30 | 1.31 | 1.38 | 1.18 | 1.18 |
| Midle | 1.22 | 1.32 | 1.08 | 1.14 |

According to the table, it can be seen that the volumetric mass of the soil varies to a certain extent depending on its predecessors, i.e. after rice sown in alfalfa layer, the soil mass decreases by 0.1 g/cm$^3$. As you can see, deep tillage reduces the volumetric mass of the arable horizon, makes it looser, and ultimately improves the physical properties of the soil. Thus, before sowing winter wheat, it decreased by 0.14 g/cm$^3$.

Thus, a decrease in the volumetric mass of the soil occurs due to the natural accumulation of organic matter in the arable horizon.

The basis for obtaining guaranteed high yields of agricultural crops is the development of resource-saving technologies for their cultivation, one of the elements of which is timely and high-quality tillage of the soil using moisture and energy-saving techniques.

Currently, in conditions of scarce water resources, the most effective method of irrigation for this zone is drip irrigation.

Drip irrigation is the leading technology among water-saving technologies, because... with its help you can save about 35-40% of irrigation water (2).

The Presidential Decree "On Approval of the Concept for the Development of Water Resources of the Republic of Uzbekistan for 2020-2030," dated July 10, 2020, outlines the expansion of water-saving irrigation technologies and aims to improve water use efficiency. It also includes the creation of a system for state support and incentives for agricultural producers who adopt these water-saving methods. The economic development plan for Uzbekistan targets increasing the area of agricultural irrigation using water-saving technologies from 175,000 hectares to 1 million hectares by 2025, and further to 2 million hectares by 2030.

The above measures were taken in order to solve the tasks set for agricultural producers: to use all types of energy resources and labor economically, which in turn requires a scientific and analytical approach.

In the modern era, when the shortage of irrigation water is increasing, special attention in our country is paid to its increase and economical use. In recent years, 472,000 hectares of land have been switched to drip irrigation, 48,000 hectares to sprinklers, and other water-saving technologies have been implemented on 97,000 hectares. These initiatives resulted in a savings of 2 billion cubic meters of water in 2023 alone. (1).

One of the main directions for the long-term development of agriculture in the republic in conditions of water resource shortages, in our opinion, is the urgent development of resource-saving technologies for cultivating saturated crops. In particular, we consider it advisable to test and adapt modern methods of irrigating crops.

Starting in 2023, the experimental farm of NPO Grain and Rice has been testing and adapting the "Smart Agricultural Technology" from Agrenosa (Israel) for growing potatoes and onions as a subsequent crop.

Planning for such a system was carried out in stages. Information about the area where irrigation will be carried out was previously collected. The topography of the area has been clarified, indicating the boundaries of irrigated areas. The mechanical composition and structure, water permeability, soil salinity and groundwater level were determined.

The advantage of “Smart Agricultural Technology” developed by Agrenosa (Israel) is that it works on an automatic basis, without human intervention. To determine the necessary factors for growth, development and ensuring high productivity, special sensors are installed that transmit this information to the main control brain. After processing the received data, the main control system commands to meet the needs of the plant. As a result, soil ph, mineralization, oxygen supply, etc. are regulated. If necessary, plant feeding is carried out with water.

Our previous research has shown that drip irrigation is the most efficient method for providing water, nutrients, and protective agents to crops. This system delivers water and nutrients directly to the plant's root zone in precise amounts and at the optimal times, ensuring each plant receives exactly what it needs for optimal growth.

Thanks to drip irrigation in the NPO, grain and rice during re-sowing yielded within 24.0 t/ha, when with the usual method 12.5 t/ha of potato yield was obtained. At the same time, 50-55% of irrigation water was saved, i.e. irrigation water consumption using the proposed technology was 5.8-6.2 thousand m3/ha, when the usual one was 11-12 thousand m3/ha; in addition, the use of expensive mineral fertilizers was reduced by 35-40% and plant protection products by 25- thirty% .

An essential factor in enhancing agricultural production and optimizing land and water resources is a comprehensive program for the development of irrigated agriculture in Karakalpakstan. The ongoing fundamental economic and social transformations in the republic highlight the urgent need for the most rational and efficient use of these resources in the region. Transitioning to a regime of rational and efficient resource use in the coming years will support food security, as outlined in the country's development strategies through 2030.

## 4 Conclusion

For the efficient use of land and water resources in conditions of water scarcity, it is advisable to optimize the sown area of rice by reducing it to 40% relative to the existing (7-field) scheme. At the same time, the maximum saturation of the crop rotation wedge allows reducing the weediness of rice fields to 89.1%, the accumulation of organic substances in the arable horizon naturally is within 27.2 t/ha. The increase in the yield of the main crops is: rice - 19.1 c/ha, winter wheat - 10.6 c/ha. In addition, the additional crop introduced into the sorghum crop rotation scheme provided 79.1 c/ha of grain yield. The proportion of grain crops in the rotation system rises to 80%, ensuring stable yields for these crops. Implementing smart agricultural technology in Karakalpakstan, which tailors water delivery to the plants' needs, addresses key issues such as conserving natural resources, establishing optimal water and nutrient conditions in the soil, achieving early and high-quality harvests, automating irrigation, maintaining soil fertility, and improving the overall environmental situation in the region.

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