Land reclamation development under conditions of climate aridity growth: experience of the Republic of Tatarstan

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Abstract. The paper investigates the issues of climate aridity growth and its impact on agronomic and economic efficiency of agricultural production in the Republic of Tatarstan. The role of complex land reclamation as one of the main directions of intensification of agriculture designed to mitigate the negative effects of drought, increase the fertility of arable land, prevent the spread of soil degradation and erosion and, of course, increase the efficiency of crop cultivation is studied. Analysis of agrometeorological observations for more than a century (1900-2021) has shown an increase in climate aridity in the region, especially in the last 40 years. The results of assessment of economic efficiency of irrigated farming in the republic show that in the existing natural and climatic conditions that 1.5% of arable land area under irrigation can produce up to 18% of crop production in Tatarstan. Underestimation of the role of land reclamation development in the agrarian policy of the state has been revealed, it should be developed at a faster pace to ensure food security of the country. On the basis of experimental studies on the basis of farms of different organisational and legal forms the high efficiency of land reclamation in combination with other innovative measures is proved. Based on the results of the research, appropriate recommendations have been developed to improve the effectiveness of state support measures, development of public-private partnership and introduction of science and technology achievements in land reclamation farming to prevent the impact of negative weather-climatic and anthropogenic factors on the economic efficiency of agricultural production and restrain the development of degradation of fertile land cover.

Keywords: integrated land reclamation, soil fertility, economic efficiency, aridity of climate.

1. Introduction

The adopted Doctrine of Food Security of the Russian Federation puts the issues of preserving state sovereignty of the Russian Federation through ensuring its food independence and security at the top of the agenda, which in the current realities is not possible without the use of intensification of farming, providing for the widespread introduction of elements of complex land reclamation, which have proved for decades high agronomic, environmental and economic efficiency, contributing not only to the preservation of fertile soil, but also to the conservation of fertile land.

The analysis of the current state of land reclamation complex shows that during all the years of agrarian reforms (except for the last 5-8 years) the above mentioned possibilities of land reclamation were underestimated in the agrarian policy of the state. Although state programmes in the field of land reclamation were adopted, but they were not supported by financing at a sufficient level for restoration of destroyed land reclamation systems and construction of new systems at a faster pace. As a result, of the available reclaimed lands, significant areas are not used for agricultural production. The research results of the All-Russian Research Institute of Irrigated Agriculture, reflected in the concept of reclamation industry development, indicate that for effective farming the area of irrigated land in Russia should be at least 10 million ha [4- 6]. So far, the country has only 4.69 million ha of such lands, i.e. twice less.

Noting the value of the conclusions, it should be stressed that the underlying causes of insufficiently full realisation of land reclamation opportunities in improving land productivity and increasing production remained insufficiently investigated, which served as the basis for choosing the topic of our research [7, 8].

The aim of the study is to analyse and evaluate the development of reclamation farming in the Republic of Tatarstan and to develop scientifically-based recommendations for its development.

2. Material and methods

Monographic, abstract-logical, economic-statistical and experimental research methods were used in the research process. The research was carried out on the basis of

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analysis and generalisation of the authors' results in the field of land reclamation economics, the process of land reclamation implementation over the years of agrarian transformations in Russia, as well as experimental studies carried out on the basis of farms of different organisational and legal forms. Official documents adopted by the governments of Russia and the Republic of Tatarstan, data from Rosstat, Tatarstanstat, the Ministry of Agriculture and Food of the Republic of Tatarstan, the federal state budgetary institution 'Tatmeliovodkhoz', agricultural organisations of different legal forms were used.

3. Results and discussion

The observed growth of agricultural production indicators over the last 5 years, indicate the growth of the effectiveness of state support measures in the sphere, improvement of the financial and economic situation of agricultural enterprises. However, despite the fact that agricultural production in Russia is gradually increasing, the problem of nutrition at the level of rational norms is still not solved [9, 10]. This requires a significant increase in the production of products of fields and farms.

A special role in ensuring the food security of the country, economic availability of food products to the population belongs to increasing the productivity of the main productive force - land on the basis of land reclamation and other innovative measures, strengthening the material and technical base of agriculture as a whole. Ameliorated lands, if used rationally, can provide a rapid and significant increase in agricultural production. Thus, up to 50 per cent of vegetable, melon and potato production, 100 per cent of rice and about 20 per cent of fodder in Russia are produced on reclaimed lands, although such lands account for only 7.9 per cent of arable land [11, 12].

In economically developed countries of the West, the area of reclaimed land reaches up to 40 per cent of the arable land, on a global scale 17 per cent is reclaimed, where more than 75 per cent of crop production is produced, in the Russian Federation in the country where more than 20 per cent of the world's fresh water reserves are located, the area of irrigated agriculture occupies less than 1 per cent of the arable land, in the Republic of Tatarstan only 1.5 per cent of agricultural land is irrigated and up to 18 per cent of crop production is produced on it, which indicates a high degree of agronomic and economic efficiency.

The development of complex melioration was promoted not only by high economic efficiency of production, but also by the growth of climate aridity in the Volga region, which led to a significant decrease in moisture availability during vegetative periods of agricultural plants.

Analysis of 120 years of data (1900-2021) of meteorological observations of average annual air temperature in the territory of the Republic of Tatarstan, shown in Figure 1 indicates that during the study period the average annual air temperature in the territory of the Republic of Tatarstan increased more than three times. [16, 17].

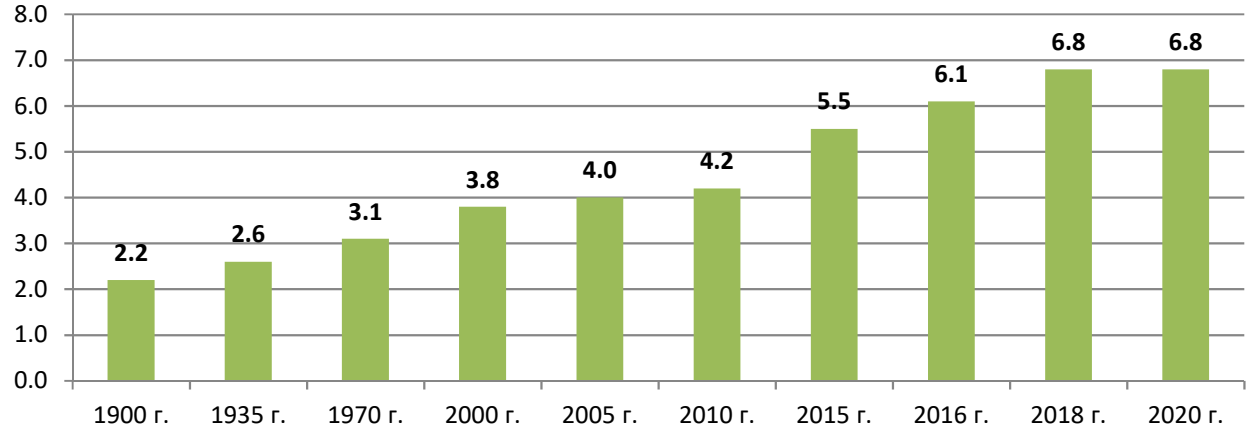

Figure 1. Dynamics of average annual air temperature on the territory of the Republic of Tatarstan 1900-2021, °C

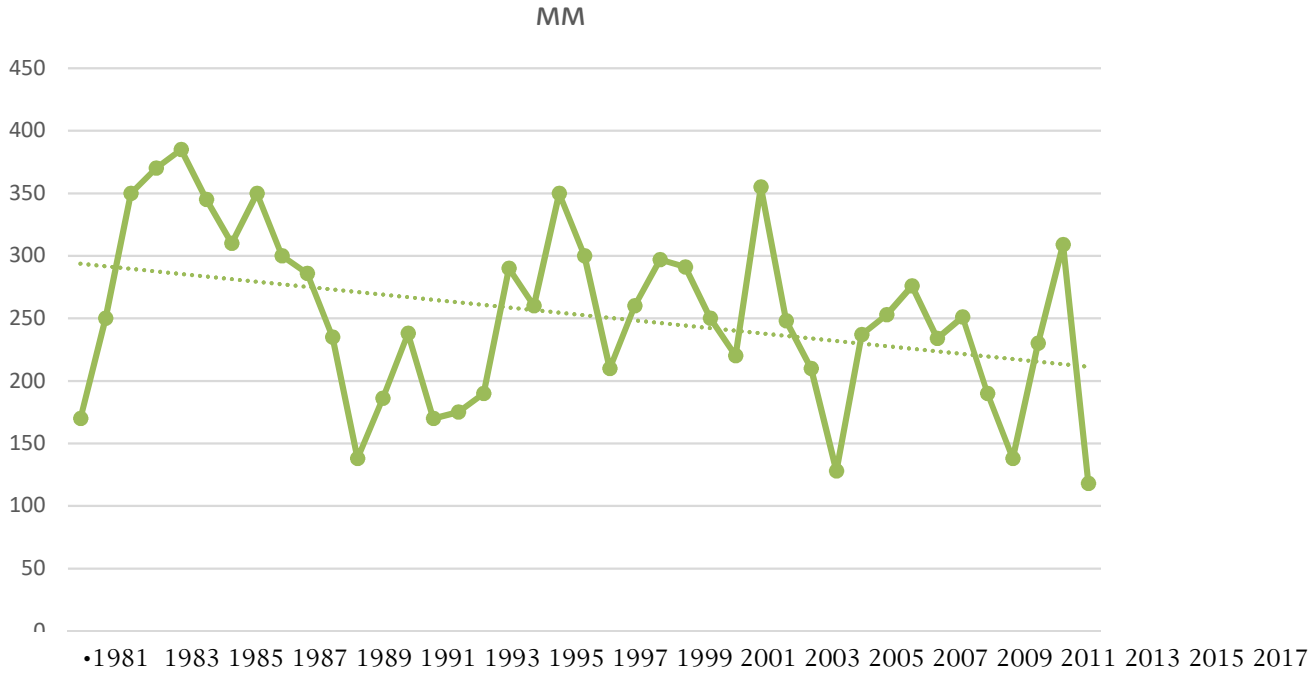

Figure 2. Dynamics of changes in the average annual precipitation in the Republic of Tatarstan for 1981-2021, mm

The study of the dynamics of the average annual precipitation in the Republic of Tatarstan for the last forty years (1981-2021) indicates a decrease in the average annual precipitation (Fig. 2) [16, 17].

The above circumstances, according to scientists of the Tatar Research Institute of Agriculture - a separate structural subdivision of the Federal State Budgetary Institution of Science 'Federal Research Centre "Kazan Research Centre of the Russian Academy of Sciences" (TATNIISKh FIC KazNTs RAS) and agrochemists of the Centre of Agrochemical Service "Tatarsky" (CAC "Tatarsky"), have led to an increase in inefficient evaporation of moisture from the soil, to a decrease in the level of groundwater table, shallowing of rivers, drying up of lakes, which affected the moisture availability of the root-inhabited layer of land, which once again proves the importance of the development of irrigation reclamation in modern natural and climatic realities. [16-18].

Increasing growth of active temperatures and decreasing volumes of precipitation lead to increasing aridity of climate on the territory of the Republic of Tatarstan, which has become more noticeable over the last 40 years, which led both the industry and republican leadership to recognise irrigation reclamation as one of the main directions of intensification of farming. As a result, not only wide participation in implementation of federal target programmes, but also development of a number of significant for the branch republican state programmes on development of material and technical base of meliorative branch, overhaul and construction of hydraulic engineering structures; technical re-equipment of melioration objects; drilling of wells for needs of agricultural enterprises; planting of field-protective forest plantations; liming of acid soils. To be fair, it should be noted that support measures for the development of land reclamation in the Republic are unprecedented, for example, when restoring hydraulic structures located on the lands of agricultural producers, 95% of the costs of the estimated cost of the object is financed from the republican budget, and to accelerate the equipping of commissioned irrigated lands with irrigation equipment, agricultural producers are reimbursed from the republican budget for 70% of the costs incurred for the purchase of such equipment [19, 20]. For 2019-2023 from the budget of the Republic of Tatarstan to finance land reclamation activities, according to the Ministry of Agriculture of the Republic of Tatarstan, in 1. 7 times more than from the federal budget, which allowed reclamation workers to build and reconstruct over 461 HS with a water volume of up to 110 million m3, to lay more than 331 km of main water pipeline, to put more than 40 thousand hectares of new irrigated lands into operation, to plant more than thirty thousand hectares of soil-protective forest belts and to preserve more than 140 thousand hectares of agricultural land from erosion [21, 22].

In this regard, the most important tool for solving the problems of food security in the context of deteriorating climatic conditions is a comprehensive land reclamation in combination with the application of knowledge-intensive agricultural technologies based on digitalisation and automation of the maximum number of agricultural processes. Taking into account the current situation of high efficiency of irrigation reclamation and based on the needs of the domestic market and the need to produce irrigation equipment in Russia, the heads of a number of enterprises of the Republic of Tatarstan and the management of the Ministry of Agriculture and Food of the Republic of Tatarstan in 2015, it was decided to establish in the Republic, namely on the basis of the Kazan branch of the Federal State Budgetary Institution

of Management 'Privolskmeliovodkhoz' plant for the production of sprinkler systems that meet all modern international standards

In 2022, a modernised sprinkler machine with an online control system was developed and in 2024, serial production was started.

Table 1. Brief characteristics of Kazanka sprinklers manufactured by Kazan Irrigation Machinery Plant

Machine modification	Kazanka-3	Kazanka-4	Kazanka-5	Kazanka-6	Kazanka-7	Kazanka-8
Number of spans	3	4	5	6	7	8
Machine length, m	204	264	324	384	444	504
Water flow rate, l/s	18.6	28.9	40.9	55.6	73.2	90.9
Water pressure at the machine inlet, kgf/cm^2	1.9	2.1	2.4	2.9	3.5	4
Irrigation area, ha	14.6	24.9	35.5	49.3	65.3	83.6
Irrigation radius, m	216	276	336	396	456	516
Average daily irrigation rate, mm	11	10.5	10.0	9.8	9.7	9.4
Minimum turnover time, h	10.5	14	17.5	20.9	24.4	27.9
Minimum irrigation rate per one turn, m^3/ha	48	60.9	72.7	85.4	98.9	110

Figure 3. Kazanka sprinkler machine operation

Main effect-forming indicators of sprinklers of Kazanka series:

- - preventing or significantly reducing the loss of land fertility by improving rain quality (Fig. 4);
- - water saving by reducing pressure in the pipeline and improving sprinkler control;
- - improvement of the technological process of irrigation and on this basis the growth of irrigated land productivity;
- - low water pressure at the hydrant 2-3 atm;
- - electric drive system;
- - programmable reversible movement through a fully functional control panel;
- - possibility to deliver not only water but also plant protection products to the plant;
- - possibility of the mobile eight-section modification of the machine to move from one hydrant to another, providing watering of plants on the area of up to 160 hectares per season (Kazanka-8");
- - possibility of remote control and monitoring of the sprinkler machine operation and functionality;
- - possibility of refreshing irrigation with small rates in a short time, combining irrigation with foliar feeding of plants;
- - programmability of all panel functions, including date and time;
- - possibility to apply with irrigation water liquids with aggressive environment (animal waste water, micro- and macro-fertilisers);
- - Expansion of irrigated farming zone and intensification of agricultural production.

Figure 4. Erosion development under irrigation by Kazanka and Fregat sprinklers

Functions of remote monitoring and control of sprinklers 'Kazanka' allow to provide: monitoring simultaneously for several installations of one user, including location and geolocation on the map of installation/installations, installation status (online/offline, power, in/out of motion, irrigation/dry running, direction of motion), installation parameters (voltage, speed (m/hour, per cent), water pressure, irrigation rate, operating time, crop), remote control through the programme - start/stop, forward/backward, set sector, start by time and time of operation, remote control of sprinklers 'Kazanka'.

Economic efficiency of the sprinkler 'Kazanka' consists of the following:

- э water saving (at 5-fold irrigation annually for the amount of 40-60 thousand rubles);
- - energy saving (at 5-fold irrigation annually for the amount of 25-40 thousand rubles);
- - grain yield growth by 20-30 centners/ha (at grain cost of 15 thousand rubles/t annually for the amount of 300-450 $/ha).

Irrigation plant 'KAZANKA' is optionally offered in mobile version, which will allow to increase the area under irrigation with simultaneous reduction of capital costs, reduction of capital investments and repair costs.

Implementation of the research results in average for 5 years provided obtaining from each hectare of irrigated fodder crops: 6.8 tonnes of grain units; 50.2 tonnes of white cabbage; 45-50 tonnes of carrots with production profitability of 125-133 % (with irrigation the production cost is 2 and more times lower than on rainfed land). In the structure of production costs, irrigation takes no more than 10% of costs in potato cultivation and 20-25% in vegetable cultivation [25]. Irrigation of agricultural crops allowed the agrarians of Tatarstan to fully provide the population of the republic with locally produced vegetables and potatoes from irrigated lands; to meet the needs of livestock of large investors and farms of the republic with fodder base from irrigated lands regardless of weather and climatic conditions, as well as the disposal of runoff in compliance with environmental requirements [26].

4. Conclusions

Analysis of long-term meteorological observations of average annual air temperature, study of dynamics of average annual precipitation on the territory of the Republic of Tatarstan has shown the growth of climate aridity on its territory, which led to the growth of inefficient evaporation of moisture from the soil, reduction of groundwater table, shallowing of rivers, drying up of lakes, which negatively affected water availability in the root layer of the land, which proves the urgent need for the development of irrigation reclamation in modern natural-climatic realities. In turn, reclamation measures allow to receive from each hectare of irrigated fodder crops: 6.8 tonnes of grain units; 50.2 tonnes of white cabbage; 45-50 tonnes of carrots with production profitability of 125-133 %. At irrigation the

cost of production is 2 and more times lower than on rainfed land. In the structure of the cost of finished products irrigation occupies no more than 10 % of expenses at cultivation of potatoes and 20-25 % at cultivation of vegetables. Irrigation reclamation has already allowed: to provide the population of the republic with locally produced vegetables and potatoes from irrigated lands; to meet the needs of livestock of large investors and farms of the republic with fodder base from irrigated lands regardless of weather and climatic conditions, as well as waste water disposal in compliance with environmental requirements. 1.5% of irrigated arable land allows agrarians of the republic to produce up to 18% of gross crop production. However, further development of complex land reclamation is impossible without cardinal improvement of the situation in the land reclamation system of the country, through significant amendments in the agrarian policy of the state in the direction of allocation of significant additional budgetary funds for reconstruction and rehabilitation of existing unused and construction of new land reclamation systems at a faster pace, development of other directions of land reclamation, training of personnel for land reclamation, creation of favourable conditions for them to work and live.

References

1. A.A. Lukmanov, R.M. Gainullin, I.G. Gainutdinov, Agrochemical Bulletin**, 2,** 3-10 (2023)
2. A.R. Valiev, N.M. Asadullin, L.V. Mikhailova, et al, Bulletin of Kazan State Agrarian University, **18(2(70)),** 199-205 (2023)
3. V.G. Sychev, Plododoroddie, 1(130), 57-63 (2023)
4. N.M. Asadullin, A.A. Lukmanov, D.F. Zaripov, et al, Agrochemical Bulletin, **6,** 65-71 (2023)
5. I.M. Minnehametova, L.F. Gafiullina, Co-operative and Sustainable Devel. and Sustainable Devel.: Conf. proc. (Moscow), (Cham: Springer Nature Switzerland, 2022), vol. **245**, pp. 1241-1248
6. M.M. Hismatullin, Bulletin of Kazan State Agrarian University, **5(1(15)),** 123-125 (2010)
7. F.N. Mukhametgaliev, N.M. Asadullin, F.N. Avkhadiev et al, Int. Sci.-Pract. Conf. Agricult, and Food Security: Technol, Innov, Markets, Human Resour. (EDP Sciences, Kazan, 2021), p. 00080.
8. I. Akzharkyn, K. Yelemessov, D. Baskanbayeva, Applied Sciences (Switzerland), **14(17),** 7567, (2024). DOI: 10.3390/app14177567
9. P.A. Chekmarev, Kormoproizvodstvo, 2, 10-12 (2012)
10. F.N. Safiollin, A.R. Valiev, S.R. Suleymanov, Bulletin of Kazan State Agrarian University, 17(4(68)), 50-55 (2022)
11. F.N. Salakhutdinov, I.R. Iskhakov, Bulletin of Kazan State Agrarian University, **6(2(20)),** 52-54 (2011)
12. F.N. Safiollin, G.S. Minnullin, S.V. Sochneva, Grain Farming of Russia, **2(50),** 29-33 (2017)
13. F.N. Safiollin, Kormoproizvodstvo, 7, 12-18 (2019)
14. F.N. Mukhametgaliev, R.G. Khisamov, Bulletin of Kazan State Agrarian University, **10(2(36)),** 31-35 (2015)
15. G.N. Agieva, L.S. Nizhegorodtseva, R.J.K. Diabankana, Bulletin of Kazan State Agrarian University, **15(4(60)),** 5-9 (2020), https://doi.org/10.12737/2073-0462-2021-5-9
16. O.L. Shaitanov, R.M. Nizamov, E.I. Zakharova, Grain legumes and cereals, **4(40),** 102-112 (2021)
17. A.A. Lukmanov, T.B. Hakimov, M.G. Kuznetsov, C.M. Kurakova, et al, Agrarnaya nauka, **5**, 136-143 (2024), https://doi.org/10.32634/0869-8155-2024-382-5-136-143
18. G.S. Minnullin, L.T. Vafina, F.N. Safiollin, Bulletin of Kazan State Agrarian University, **6(1(19)),** 160-162 (2011)
19. F.N. Avkhadiev, N.R. Aleksandrova, I.G. Gainutdinov, Bulletin of Kazan State Agrarian University, **17(1(65)),** 108-113 (2022), https://doi.org/10.12737/2073-0462-2022-108-113
20. O. V. Afanaseva, O. K. Bezyukov, A. A. Ignatenko, Academic Journal of Manufacturing Engineering, **22(1),** 68–75, (2024). DOI: 10.24874/PES.SI.02.017
21. S. I. Kondratyev, D. Baskanbayeva, K. Yelemessov, Y. Sarsenbayev, V. A. Turkin, International Journal of Hydrogen Energy, **95,** 212–216, (2024). DOI: 10.1016/j.ijhydene.2024.11.182
22. K. Zaurbekov, A. Syzdykov, S. Zaurbekov, J. Ismailova, Chemical Papers, **78(8),** 4867–4873, (2024). DOI 10.1007/s11696-024-03436-z
23. D.F. Khafizov, E.S. Isaicheva, Bulletin of Kazan State Agrarian University, **8(1(27)),** 55-58 (2013)
24. D.F. Khafizov, E.S. Isaicheva, Bulletin of Kazan State Agrarian University, **6(1(19)),** 82-84 (2011)
25. R.M. Nizamov, S.R. Suleymanov, F.N. Safiollin, Bulletin of Kazan State Agrarian University, 13(1(48)), 38-40 (2018)
26. I.G. Gainutdinov, N.M. Asadullin, A.K. Subaeva, L.V. Mikhailova, Bulletin of Kazan State Agrarian University, **18(1(69)),** 102-111 (2023)