

The current state and directions of fertility provision for agricultural lands based on biologically active substances

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Abstract. The paper examines the current state of the land fund, farmlands and agricultural lands in the context of federal districts and individual subjects of the Russian Federation to ensure the increase in production of products obtained by traditional agricultural technologies and organic farming. Qualitative indicators of farmlands and agricultural lands, including indicators of unfavorability, are analyzed. Separately, the problems of fertility regulation (maintenance of humus-forming processes) of farmlands are considered in the conditions of their intensive use on the basis of modern methods of soil fertility reproduction - the introduction of balanced complex fertilizers, reclamation, the use of energy-saving agricultural technologies of tillage, rotation of crop rotations, the introduction of special biologically active substances into the soil, the cultivation of siderates, etc.

1 Introduction

On the territory of the Russian Federation, the bulk of crop production is produced in the zone of risky farming. At the same time, the quantitative and qualitative indicators of the products produced, including organic ones, largely depend on the efficiency of the use of land resources. The yield and quality of products is determined by a combination of many factors and conditions – the presence of natural soil fertility, the maintenance of ecological balance and stability of the agricultural landscape, the approximation of the functions of agroecosystems (the intensity of agricultural production) to the functions of natural (nature) ecosystems, compliance with crop rotations and the order of fruit-bearing, the use of modern safe fertilizers and plant protection products.

The priority tasks of agro-industrial and trade policy established in the National Project "International Cooperation and Export" place high demands on domestic products and food products in terms of ensuring the quality, safety, and competitiveness of Russian goods (works, services) in foreign markets. One of the main guidelines of the National Project is to increase non-primary exports of agricultural products to 45 billion US dollars per year (by 2024).

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This, in turn, leads to more intensive use of the soil and, first of all, agricultural land - arable land, hayfields, pastures, etc. Soil is a complex biological system in which its microflora is the main factor of soil formation, self-cleaning ability, and circulation of substances.

On the one hand, the possibilities of more productive use of agricultural land are limited by the high ploughing of land (72-86%) and the reserves available in them (the amount of compounds of biophilic elements and other substances in the soil that contribute to the growth of biocenosis productivity and stability), a strong negative anthropogenic impact on the state of agricultural landscapes by applied fertilizers (primarily mineral) and synthetic plant protection products (pesticides, herbicides, fungicides) [1,2], the use of energy-saturated technical means with a high specific pressure of driving units that destroy the structural and aggregate state of the soil, adverse weather conditions during the growing season (frost, hail, dust storms, floods, abnormally high temperatures), the repeatability of cultivated crops that are in economic turnover (monocultures, unilateral removal of nutrients). The combination of these factors leads to a decrease in the humus content of the soil (humus content in the arable layer), erosion processes progress, the stability of landscapes and biocenoses is disturbed.

On the other hand, the presence of unused farmlands, lands with low natural fertility (with insufficient capacity of the humus horizon) and uneven state of the agro-climatic regime during the year (waterlogging, lack of heat and moisture exchange, stony and gravelly, salinity, carbonate, etc.), as well as agricultural conditions with unfavorable relief (highlands, soils with large slopes). Separately, it is necessary to note the presence of ownerless lands, in respect of which the owners (if any) do not carry out appropriate measures for their maintenance to exclude natural fertility degradation.

The gradual decrease in the natural fertility of the soil as a result of its incomplete reproduction ultimately leads to the fact that its maintenance requires an increasingly massive and expensive human impact on the soil, which often leads to a further decrease in its potential.

Thus, considering the need to achieve the targets of agro-industrial and trade policy defined in [3], modern agricultural production should be carried out in such ways that would contribute to the replenishment of the productivity of the agricultural sector, excluding or limiting adverse effects on the soil, as well as ensuring the growth of soil fertility indicators, improving the macrostructural condition, biological activity, and sanitary-protective state of the soil.

As a rule, a set of measures is used for this purpose, providing for the optimization of the agrophysical state of the soil, bringing the physico-mechanical and physico-chemical properties to physiologically normal conditions and balancing the nutrient regime of the soil in accordance with the biological requirements of plants.

Modern methods of soil fertility reproduction are based on the following basic measures – the use (application) of balanced fertilizers, land reclamation, the use of energy-saving agricultural technologies of tillage, rotation of crop shifts, introduction of special biologically active substances into the soil, cultivation of siderates, etc. [4, 5].

The most expensive and promising direction is land reclamation (geo-, hydro-, aero-, phyto-, chemical reclamation) and land management on a landscape-ecological basis, especially agricultural land with unfavorable soils, considering the stimulation of biota by biologically active substances [6,7]. Taken together, this approach will improve the productive properties of the farmlands, ensure an increase in yield, the quality of the products obtained and reduce crop loss [8].

2 Materials and Methods

The article uses methods of system analysis and synthesis, indirect measurement, comparison, and information modeling.

3 Results

The land fund of the Russian Federation includes several categories of land: farmlands, lands of settlements, industry, energy, transport, etc., forest, water fund, and reserve.

In the context of the current study, farmlands will be analyzed, since they are the main means of production in agriculture. This category includes lands assigned to agricultural organizations, farms, land plots provided to citizens for personal subsidiary farming and a number of others.

At the beginning of 2022, there were 1,712.5 million hectares of land in the country, including 114.1 million hectares (6.7%) registered in private ownership of citizens, 19.1 million hectares (1.1%) of legal entities. There were 1,579.3 million hectares (92.2%) owned by the Russian Federation, the subjects of the Russian Federation, as well as local (municipal) authorities.

Farmlands accounted for 22 % or 380.5 million hectares. The largest number of farmlands is concentrated in the Siberian Federal District – 96.1 million hectares or 25%, the Far East 66.8 million hectares (17.4%), the Volga region 57.4 million hectares (14.9%), and the Urals 12.7% (49.1 million hectares). In the Southern, Northwestern, and Central Districts, 9.2% (35.3 million hectares), 9.1% (34.9 million hectares), and 8.1% (30.7 million hectares) were registered, respectively (Figure 1).

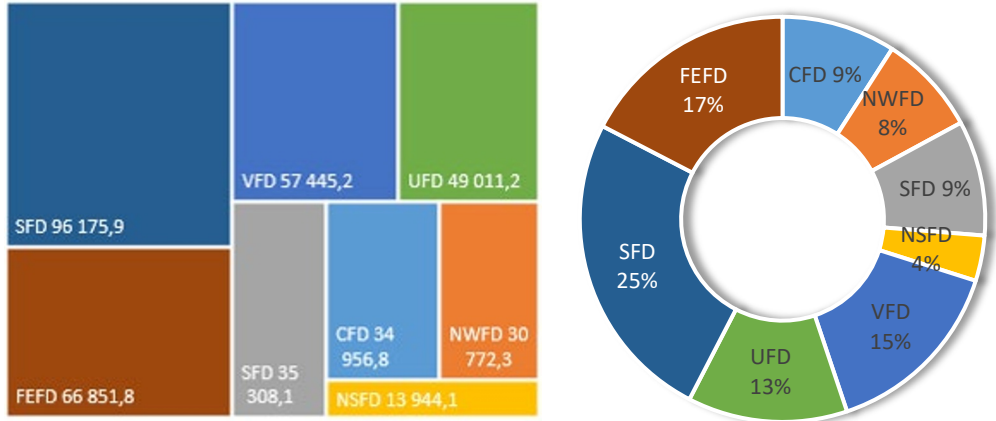


Fig. 1. The structure of farmlands by federal districts (left million hectares). Compiled by the authors on the basis of sources [9]

According to its intended purpose, it is customary to allocate agricultural lands that are used or suitable for use for specific economic purposes in accordance with their actual condition – arable land, fallow, perennial plantations, hayfields, pastures, other land types. Also, lands that are not suitable for farmlands that have a technical or maintenance purpose (land under buildings, structures, on-farm roads, forest plantations, water bodies, etc.).

Thus, at the end of 2021, the total area of farmlands amounted to 198.4 million hectares (51.6% of the farmlands), while the largest areas of farmlands are in the PFD 51.2 million hectares (25.8%), NFD 49.9 million hectares (25.2%), SFD 32.0 million hectares (16.1%),

and CFD 29.4 million hectares (14.8%), aggregating almost 82% of the total area of agricultural land in the Russian Federation (Fig. 2 on the left).

Analysis of farmland distribution by type shows that almost half falls on arable land – 115.7 million hectares (52.1% of farmlands), pastures occupy 58.5 million hectares (26.3%), hayfields – 18.0 million hectares (8.1%), deposits – 3.9 million hectares (1.7%), perennial plantations – 1.9 million ha (0.9%) (fig. 2 on the right). The area of non-agricultural land in the structure of agricultural land in 2021 amounted to 182.9 million hectares.

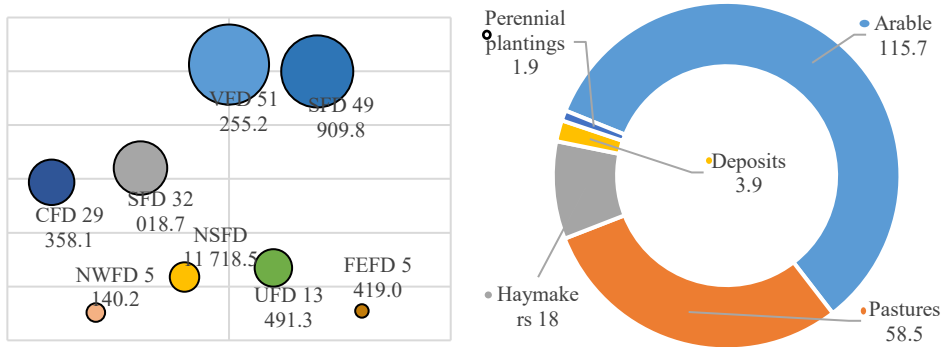


Fig. 2. Structure of farmlands area (on the left by FD, million hectares, on the right by type, %). Compiled by the authors on the basis of sources [9,10].

An important qualitative characteristic of the state of farmlands is the content and reserves of organic matter (humus). According to the results of a sample study conducted by the Ministry of Agriculture of Russia in 2021, the content of organic matter in soils varies greatly depending on the natural zone and the agro-climatic state. For example, 10.3% of soils or 1.14 million hectares (of the surveyed area) have a very low humus content in the arable layer, with a low humus content recorded – 41.7% (4.62 million hectares), average – 29.2% (3.24 million hectares), increased - 14.5% (1.61 million hectares), high – 3.2% (0.35 million hectares), and very high – 1.1% (0.11 million hectares) [10].

Using another example, we will show the distribution of the area of soils with very low and low organic matter content by federal districts. In the Central FD of soils with a very low humus content, 17.2% (relative to the area surveyed in the district), Southern 15.7%, Far Eastern 12.7%, and Northwestern 10.9% were registered. Relatively low values were found in the Volga (7.6%), Siberian (4.3%), and North Caucasus (2.9%) federal districts. On the territory of the Ural Federal District, such soils were found on an insignificant part of the surveyed area (0.8%) [10].

No less important qualitative characteristic of the state of agricultural land are unfavorability indicators. This is understood as a set of soil quality indicators that characterize the degree of decline in its fertility, which are difficult to regulate by anthropogenic impact, but at the same time can have physically measurable values (metrics) of growing conditions of crops that have a close correlation with yield.

According to [8], the following negative soil indicators can be used as separate metrics of soil quality: the proportion of sandy soils, the proportion of salt marshes, the proportion of soils with a groundwater level above one meter, the proportion of soils with a permanently frozen layer of more than 0.5 m, the proportion of merged soils, the proportion of this soils, the proportion of strongly rocky soils, the proportion of medium-strongly and very strongly acidic soils, the proportion of degraded soils, the proportion of lands with an absolute height above 600 meters, the proportion of lands with slopes of different exposure and steepness (more than 15%) and a number of others.

To be able to use these metrics, it is necessary to quantify them, which would consider the significance of each of them. To do this, using the taxonomy methods, a system of criteria is proposed with the determination of the significance (weight) of each of them, which are grouped into a hierarchical group according to the presence of soil area with unfavorable factors:

- Group 1 - unfavorable soils of lands from 0 to 25%;
- Group 2 - unfavorable soils of lands from 25 to 50%;
- Group 3 - unfavorable soils of lands from 50 to 75%;
- Group 4 - unfavorable soils of lands more than 75%.

Further, this set of criteria was superimposed on the statistical data given in [11], on the basis of which an adaptive model was built with the possibility of changing the weight of metrics to form dynamic comparison results (see Fig. 3).

Analysis of the simulation results shows that it is conditionally possible to distinguish several natural zones that differ in terms of unfavorability. Thus, the close occurrence of groundwater, the predominance of sandy rocks over a long period of the soil horizon (50-90% of the surveyed soils) is observed on Sakhalin, in the Vladimir, Ivanovo, Bryansk regions and the Republic of Karelia (Fig. 3 pos. 1). Stony (gravelly) (75-100% of the surveyed soils) is most common in the Altai Territory, Kamchatka, the Republics of Altai, Komi, Dagestan, Saratov, Vologda, and Irkutsk regions (Fig. 3 pos. 2).

Highly acidic soils (75-100% of the surveyed soils) are common in Sakhalin, the Republics of Karelia, Komi, Murmansk, Arkhangelsk, Vladimir regions. Acidic soils (50-75% of the surveyed soils) prevail in the Kemerovo, Bryansk, Leningrad, Tomsk regions, the Republics of Altai and Mordovia (Fig. 3 pos. 3).

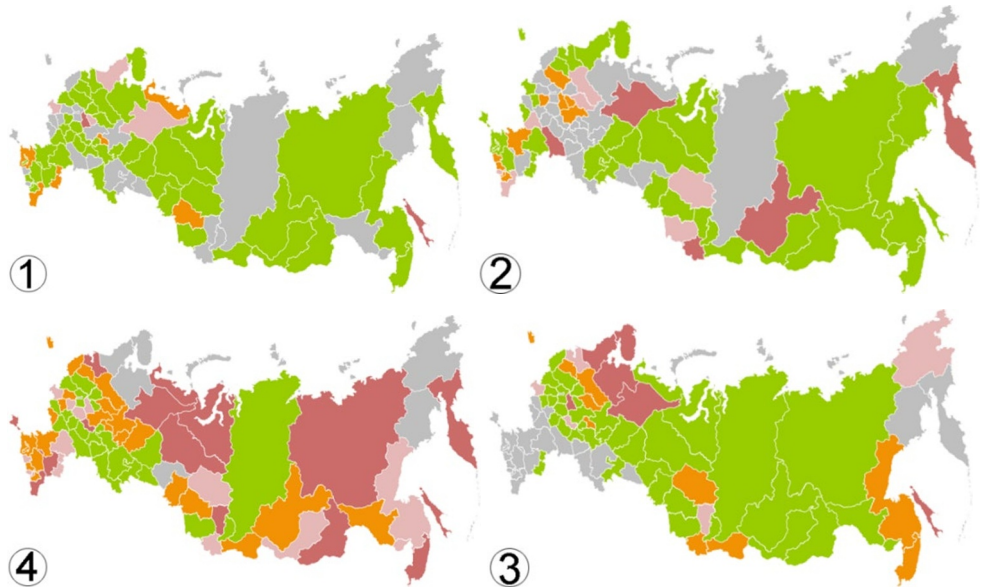


Fig. 3. Graphical interpretation of results of unfavorable factors of soils (fragment) simulation. Compiled by the authors on the basis of sources [11].

Legend:

- Group 1 - lands with unfavorable soils from 0 to 25%
- Group 2 - lands with unfavorable soils from 25 to 50%
- Group 3 - lands with unfavorable soils from 50 to 75%;
- Group 4 - more than 75% of lands with unfavorable soils

A noticeable decrease in productivity due to soil degradation (75-100% of the surveyed soils) for various reasons is noted in the Kamchatka and Primorsky Territories, the Republics of Dagestan, Mordovia, Kalmykia, Sakhalin region, Khanty-Mansijsk Autonomous District, the Republic of Sakha (Yakutia), Komi, Nenets Autonomous District, Yamalo-Nenets Autonomous District, Leningrad regions. In other regions, the degradation of arable soils ranges from 0 to 50%. In general, at the moment there is no reason to talk about a significant improvement in soil quality. There is some "transformation" of the areas of degraded soils (reduction of these areas with low productivity indicators in some regions and an increase in others).

Separately, it is necessary to note the so-called "unused" agricultural land. Unused farmlands refers to lands potentially suitable for cultivation and use, but which are currently not used for their intended purpose for various reasons, for example – land plots are not registered, do not have an owner and are not allocated in kind, land that is not in demand in sparsely populated areas or with a significant removal of infrastructure, areas that are subject to erosion, salinization, waterlogging, overgrowth of woody and shrubby vegetation, swampy areas, the operation of which is economically impractical.

The analysis of the size of unused farmlands shows that despite the fact that their volume decreases from year to year, nevertheless they have a significant size. Thus, according to the ROU AIC at the end of 2020, the total amount of unused farmlands amounted to 51.9 million hectares, including unused farmland of 31.3 million hectares and unused arable land of 18.8 million hectares. The largest share of unused farmlands was recorded in the PFD – 23.4% and the CFD – 21.2% (of the total size of the farmlands). The largest share of unused farmlands is noted in the NWFD – 49.2%, the Far Eastern Federal District – 26.6%, the UFD – 24.7%, and the Central Federal District – 20.8% (of the total size of unused farmland). The largest share of unused arable land was recorded in the Northwestern Federal District – 44.5%, Central Federal District – 20.2%, Ufa – 17.1% (of the total size of unused arable land) (Fig. 4).

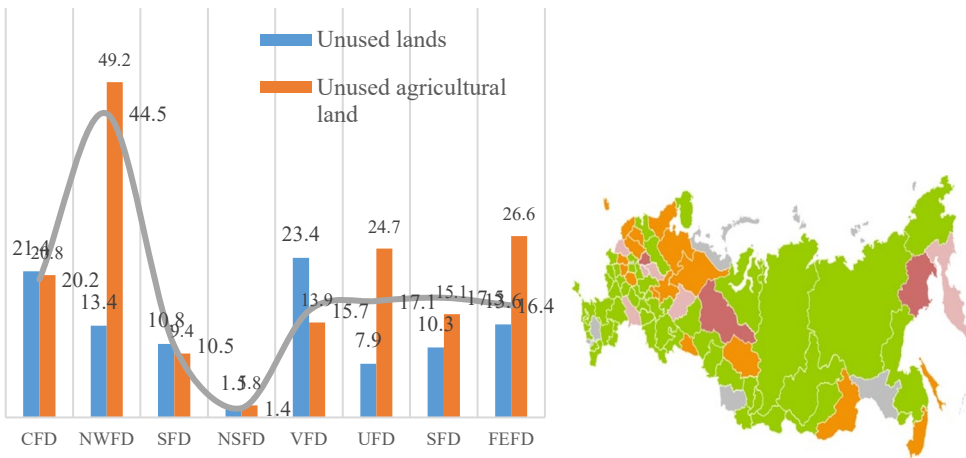


Fig. 4. The structure of unused farmlands by FD (in % of the examined farmlands). Compiled by the authors on the basis of sources [9, 10].

4 Discussion

A selective analysis of the indicators of the state of farmlands, including agricultural lands, shows that qualitative and quantitative indicators of the state of soils are at an insufficiently high level.

To overcome these negative factors, the Ministry of Agriculture of the Russian Federation initiated (extended) the State program for the effective involvement in the turnover of agricultural land and the development of the reclamation complex for the period 2022-2031 (hereinafter – the State Program, SP) with a total amount of funding - 754.5 billion rubles [12-14].

The State Program outlines five goals, including:

"...goal 2 involvement in the turnover of agricultural land with an area of at least 13234.8 thousand hectares by the end of 2031...";

"...goal 3 conservation of farmlands and chemical soil reclamation on arable land by the end of 2031 on an area of at least 2895.2 thousand hectares...";

The state program has five directions (subprograms), including:

«...I. Creating conditions for effective involvement in the turnover of farmlands...";

«...II. Complex land reclamation for agricultural purposes...".

The current indicators of the State Program indicate that as of January 1, 2022, there were 11,219.3 thousand hectares of reclaimed land in all categories of land, of which 9,307.6 thousand hectares were farmlands.

Irrigated farmlands occupied an area of 4551.0 thousand hectares, drained agricultural land – 4756.6 thousand hectares. Good land reclamation condition was observed on an area of 2944.4 thousand hectares of farmlands, satisfactory – on an area of 3619.9 thousand hectares and unsatisfactory – on an area of 2743.3 thousand hectares. The total area on which land improvement and the technical level of reclamation systems are required amounted to 5987.2 thousand hectares.

Half of the irrigated lands are located in the south of Russia. Significant areas of land are irrigated in the Republics of Crimea (397.3 thousand hectares) and Dagestan (395.6 thousand hectares), Krasnodar (388.5 thousand hectares) and Stavropol (213.8 thousand hectares) territories, Rostov (236.3 thousand hectares), Astrakhan (210.9 thousand hectares), and Volgograd regions (180.7 thousand hectares) [10].

The area of irrigation of agricultural crops in 2021 was 85.16%. According to the reclamation state, the level of groundwater occurrence and the degree of salinization of irrigated lands are distributed as follows: 64.6% are in good condition, 23.4% are satisfactory, and about 12% are unsatisfactory. The drained lands according to the reclamation state are distributed as follows: in good condition – 24.2%, satisfactory – 39.6%, and unsatisfactory – 36.2%.

During 2020-2021, 121.4 thousand hectares of reclaimed land (drained and reclaimed) were put into operation, 143.8 thousand hectares were protected from wind erosion due to agroforestry and phytomeliorative measures, 609.45 thousand hectares of retired agricultural land were involved in turnover due to cultural measures. Agrochemical works (chemical melioration) were carried out almost in full – liming was carried out on an area of 3282.2 hectares, phosphorization – 9.9 thousand hectares, gypsum – 0.3 thousand hectares. The application of organic fertilizers amounted to more than 75.6 million tons, mineral 35.3 million tons (Fig. 5).

The implementation of the State Program assumes that by 2031 the following indicators will be achieved (only in direction II):

5 million hectares of retired farmlands are involved in the turnover due to crop-engineering events;

hydro-reclamation measures were carried out on an area of 853.5 thousand hectares on farmlands;
 protection from degradation and preservation of the stability of agricultural landscapes on an area of at least 624 thousand hectares has been carried out through agroforestry and phytomeliorative measures;
 acidic soils were cultivated on arable land on an area of up to 2.27 million hectares.

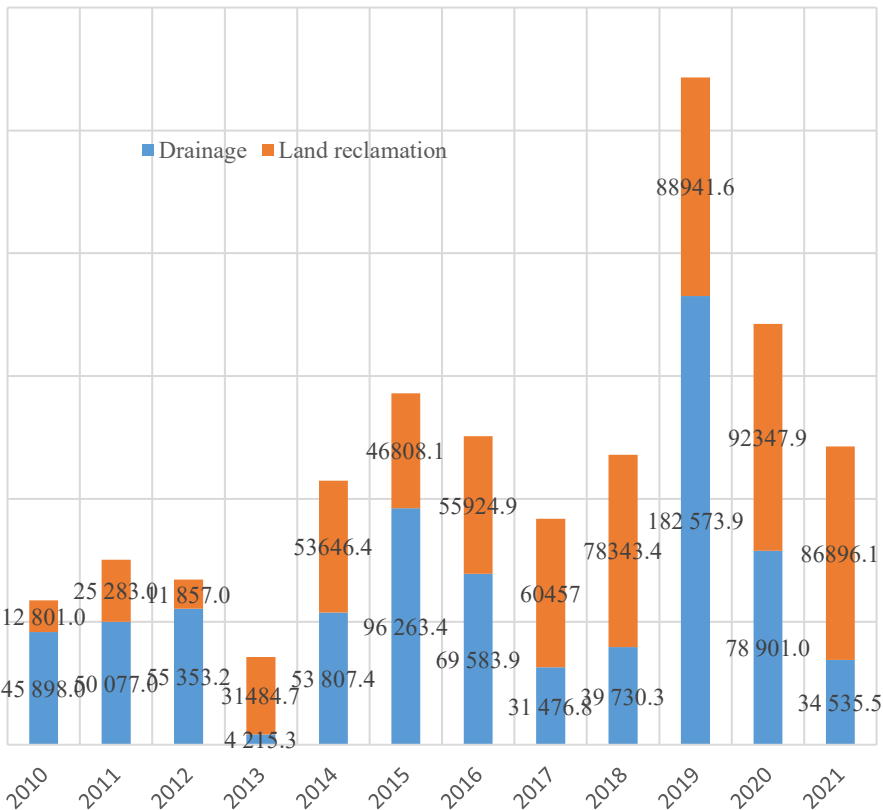
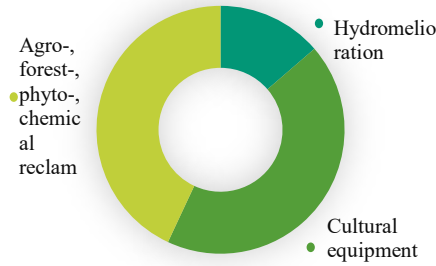


Fig. 5. Structure and volume of the performed reclamation works (left, %, right, ha). Compiled by the authors on the basis of sources according to the ROU AIC.

The generalizing criterion for the effectiveness of the program implementation will be an increase in production (increase), considering the complex of implemented measures by 2031 (Fig. 6).

5 Conclusion

The problem of degradation of farmland and agricultural lands in recent years continues to be relevant. Thus, according to the results of a sample survey, it was found that 52% of the soils (of the surveyed area) have a low and very low humus content in the arable layer. About a third of the surveyed areas are unfavorable (the presence of weak soils, sandstones, high groundwater level, high freezing level, stony, salinization, the presence of acidic soils, etc.). In addition, about 51 million hectares of land have been recorded that are not used for various reasons (legal, social, technological, economic, etc.).

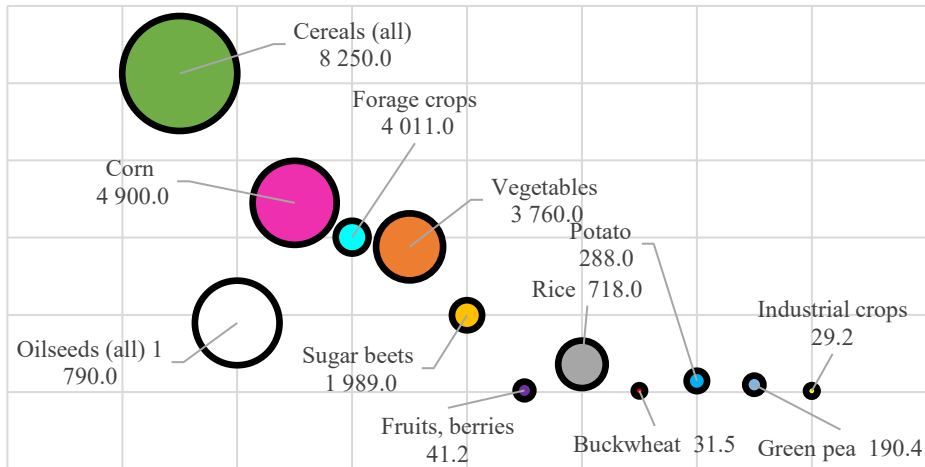


Fig. 6. Increase in production from the implementation of the State Program, thousand tons. Compiled by the authors on the basis of sources [13].

At the same time, to achieve the priorities of agro-industrial and trade policy, it is necessary to increase the manufacture of agricultural products, including organic and food products. To do this, first of all, it is necessary to maintain and develop the qualitative characteristics of farmlands and agricultural lands. Modern methods of soil fertility reproduction are based on the following basic measures – the use (application) of balanced fertilizers, reclamation (geo-, hydro-, aero-, phyto-, chemical melioration), the use of energy-saving agricultural technologies of tillage, crop shifts of crop rotations, introduction of special biologically active substances into the soil, cultivation of siderates, etc.

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