Modern techniques and methods of returning farmland to agricultural turnover

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Abstract. We present the results of a study of the modern techniques and methods of returning farmland to agricultural turnover in the Leningrad region, Russia. Agrophysical Research Institute has been conducting scientific research on the use of remote sensing methods for surveying agricultural lands using unmanned aerial vehicles. New technologies make it possible to obtain high-precision digital elevation models, which cannot be done using traditional methods. It is also advisable to note the economic side of this problem. The use of an automated system significantly reduces the time spent on surveying overgrown lands, and also avoids significant labour costs associated with visual inspection of these fields.

Introduction of precision farming, the core of which is primarily information technology, will give a powerful impetus for the development of crop production in our country, transfer the industry to a qualitatively new level of production, and increase attractiveness of the industry for young workers. This requires the conditions for effective implementation of resource-saving technologies in agricultural production: the creation of a domestic physical-technical and software-mathematical basis, as well as databases and knowledge on the information support of agriculture and crop production.

1. Introduction

Russia has an enormous potential for the development of the agro-industrial complex, ranking first in the world in terms of land resources (over 1.7 billion hectares), third in terms of arable land (116 million hectares) and fifth in terms of agricultural land (192.7 million hectares) [1, 2]. However, over the past 30 years, a number of problems have emerged that need to be addressed in order to successfully realize this potential. By 1990, our country had the largest volumes of acidic soils melioration, which amounted to 6.5 million hectares (table 1). Although, according to the calculations of scientists, taking into account the five-year cycle of liming, in order to achieve and maintain an optimal pH levels, it is necessary to introduce ameliorants on an area of 10 million hectares with a single dose of 10 tons annually. The liming program had started in 1969, and over 20 years it created a positive balance of calcium in agriculture and significantly reduced the area of strongly acidic soils [3, 4]. For comparison, in Western Europe lime has been used in agriculture for more than 200 years [5,
6]. However, by the beginning of the third millennium, in our country the economic conditions for agriculture had changed. State support for soil fertility maintenance sharply decreased, and most farms did not have sufficient financial resources to organize liming. The area of arable land has been significantly reduced: in 1990 there were 132 million hectares, but now there are only 116 million hectares left. The sown area in 1990 was 117 million hectares, and in 2020 there were 80 million hectares left, that is, it decreased by 37 million hectares. Since 1990, the rate of liming of soils has fallen sharply; by 2016, its volumes decreased by thirty times. The application of mineral fertilizers during this period decreased from 112 to 38 kg per ha, and organic fertilizers, from 10.5 to 1.1 tons per ha (table 1). The country produces about 20 million tons of mineral fertilizers, of which only 3.4 million are used in the country, and the rest is exported. Despite the decrease in the doses of mineral and organic fertilizers, there is an increase in the yield of grain and leguminous crops from 13.2 to 23.9-26.2 centner per ha. This can be explained by the fact that since 2000, agricultural producers have been taking poorly cultivated soils from turnover, on which the cultivation of agricultural crops was not profitable.

Table 1. Dynamics of the use of agrochemicals, and the yield of cereals and leguminous crops.

| Indicators                  | Unit of measurement | 1990  | 2005  | 2013  | 2015  | 2016  | 2018  | 2019  |
|-----------------------------|---------------------|-------|-------|-------|-------|-------|-------|-------|
| Volumes of liming           | thousand hectares   | 6500  | 350   | 210   | 238   | 215   | 250   | 775   |
| Mineral fertilizers used    | kg per ha           | 112.0 | 25.0  | 37.0  | 38.0  | 37.0  | 38.0  | -     |
| Organic fertilizers used    | t per ha            | 10.5  | 0.9   | 1.0   | 1.1   | 1.1   | 1.1   | -     |
| Yield of cereals and legumes| centner per ha      | 13.2  | 18.8  | 23.8  | 23.9  | 26.2  | 25.9  | -     |

On the other hand, modern technologies and methods of farming make it possible to produce more products per unit area; therefore, the most fertile soils are used first. However, on such lands the formation of yield takes place mainly due to the use of nutrients from soil reserves, which leads to a sharp decrease in their fertility. According to the Ministry of Agriculture of Russia, over five years, from 2006 to 2010, 45 million tons of active substances were taken out of the soil with the harvest of agricultural crops, and only 10 million tons were returned to the soil. Thus, the five-year negative balance amounted to 35 million tons of active ingredient. In the next five years, from 2012 to 2016, 51.7 million tons were removed from the soil, and 21.9 million tons of active substances were added. The negative balance amounted to 29.8 million tons of active ingredients. According to researchers, in Russia, about 56 million hectares of land intended for agriculture, in connection with their intended purpose, have been withdrawn from turnover. As a rule, they are located on lands that are of little use for agriculture, but with the most favorable conditions for growing forests [7, 8]. According to experts, forests occupy at least 60 million hectares of agricultural land, which is about 7% of all forests in Russia. It is estimated that the area of farmland already overgrown with closed forest is at least 30 million hectares, and at least 20 million hectares are accounted for by overgrown farmland, which in modern conditions cannot be returned to agricultural use. These ca 60 million hectares taken out of cultivation and overgrown with forest, which are not supposed to be returned to agricultural use or used to restore valuable non-forest ecosystems and landscapes, that can be used for productive forestry [9-12]. In the long term, up to 300 million m³ of timber can be obtained from such an area annually, and, which is very important, up to 100 thousand new jobs may appear in rural areas suffering from unemployment. On the other hand, the additional volume of harvested wood will help reduce the load and protect primary forests, where many rare species of animals and plants live. This
invasion will help fight forest fires, and for the next 100 years these forests will be able to absorb an average of 580 million tons of carbon dioxide annually. Fields became overgrown at different times and for different reasons. In the 20th century, it happened because of wars and other social upheavals. Among the latter was the collapse of the Soviet Union and the following severe economic crisis that broke out in Russia. The use of abandoned lands was not possible due to the lack of economic and social incentives for development, in connection with the processes of urbanization. A reduction in the area of agricultural land is typical for almost all constituent entities of the Russian Federation, especially for the Non-Black Earth Region, the northern part of Central Russia, the North-West and other regions. On unused agricultural lands, a natural process of succession of plant communities occurs, which will lead to the restoration of the original vegetation and significant changes in the state of old arable soils. The territory is first colonized by herbaceous, then shrubby and woody vegetation. Numerous studies established that the following four woody species participate in the formation of forest stands on post-agricultural lands most often: pine, alder, birch and willow. It is noted that stands formed by these species have advantages in comparison with similar stands growing on primary lands of the forest fund [7-12]. Taken out from agricultural use lands have a levelled arable horizon and a higher productivity class. The acidity of these soils is also less than that of forest soils, which makes the elements of mineral nutrition more accessible for tree species [11, 12]. At present, the number of areas covered with woody vegetation on lands previously used for agricultural use is increasing. The reasons for this process have a social basis and are caused by a number of economic and political factors. The withdrawal of land from agricultural use is a common practice in countries with market economies. In 1961-2003, in Western Europe more than 25 million hectares of agricultural lands were taken out of cultivation; in the USA, 35.6 million hectares; in Australia, 40.8 million hectares; and globally, 223 million [5-7]. In many European countries, the use of former agricultural land for the cultivation of artificial stands is an established land use practice and reflects a decline in traditional agricultural practices. This often occurs in areas unsuitable for crop cultivation, unused pastures, areas with steep slopes, poor soils, or poor road infrastructure. With land use change, the system of land assessment and technological methods of their use are changing. If the fertility of agricultural areas is mainly supported by a complex of agrotechnical and agronomic techniques, the fertility of forest lands is assessed by forest productivity, which is an integral indicator of the interaction between the parent rock, drainage conditions, vegetation and climate. Forest ecosystem is self-sufficient, that is, it provides itself with the required nutrients. The criteria used to evaluate agricultural land and forest soils are different. The difficulty in predicting the potential productivity of forest plantations is that there are no indicators on which the fertility of lands would directly depend, especially those with a history of different economic uses. Indicators that are common in assessing forest and agricultural areas are related to the parent rock and hydrological regime. According by researchers with the difference in the pathways of soil formation on 20 agricultural and forest areas, the general indicator of fertility is the content of organic matter in the upper soil layer [7, 10]. Reforestation processes on lands taken out from agricultural use were studied in various constituent entities of the Russian Federation [7-12]. Lands with significant area, which from the legal point of view are arable land, but at the same time without recent agricultural activity, during the first 8-12 years after the termination of agricultural use pass into the fallow (mortgage), and form the initial stage of fallow. Forests that are in one way or another related to agricultural land, based on their current legal status in Russia, can be divided into three main categories. Firstly, these are reclamation protective forest plantations specially grown to protect agricultural lands from adverse environmental factors; there are about 6 million hectares of those in our country, with their legal status regulated by the recently introduced amendments to the federal law "On Land Melioration". Secondly, these are the former collective and state farm forests; there are about 40 million hectares of those in our country, most of which are now at various stages of transfer from agricultural lands to forest lands, and have a controversial or double status. Thirdly, there are forests that have grown on abandoned agricultural lands. Until recently, the legal regime of forests on agricultural lands remained unregulated. It is impossible to legally use forest on these lands, since the relevant activity is not regulated, and if not used, then this is a violation of the
requirements for the protection of agricultural lands. Currently, there are clear rules for the use of forests growing on agricultural land. By October 1, 2022 or within two years from the date of registration of the right to the land plot, the owners of such areas must send notifications about the type of forest use to the governing body of the agro-industrial complex of the constituent entity of the Russian Federation, Rosselkhoznadzor and Rosreestr. In this case, overgrowing of a site with trees and shrubs will not be a sign of non-use for its intended purpose or use in violation of the legislation of the Russian Federation. The right holder can at any time decide to terminate the use of forests located on the corresponding land and to involve such land in agricultural turnover. He must notify the same authorities about this decision as about the decision on the use of forests. However, if the former arable land has not been cultivated for more than ten years, then its transition to active agronomic activity is impossible without agrotechnical work and agrochemical melioration. The Ministry of Agriculture of Russia has been paying increased attention to the involvement of unused agricultural land in a turnover, which is a key factor in ensuring the intensive development of the agro-industrial complex. Effective management of these lands will help to meet critical challenges in ensuring food security and building export potential. According to the management bodies of the agro-industrial complex, in 2019, 1.07 million hectares of unused arable land were returned into turnover in the country as a whole. Since 2021, this task has been carried out within the framework of the State Program for the effective involvement of agricultural land in a turnover and the development of the melioration complex of the Russian Federation. By the end of 2030, the Ministry of Agriculture plans to bring into turnover at least 12 million hectares of agricultural land, which will be facilitated by state support instruments. This work will ensure an annual increase in grain production by 1 million tons.

2. Methods and Materials
For a number of years, the Agrophysical Research Institute has been conducting scientific research on the use of remote sensing methods for surveying agricultural lands using unmanned aerial vehicles [13, 14]. Remote sensing of the Earth (ERS) is a process of obtaining information without direct contact with the object under study. ERS is enabled by special devices recording electromagnetic waves reflected and emitted by the Earth's surface. By measuring the intrinsic or reflected radiation of an agricultural field in the optical or radar ranges, it is possible to determine properties of crops, soils and assess the state of amelioration systems. According to optical characteristics of plants, it is possible to control their water and nutrient regimes, and carry out protection of crops from weeds, pests and diseases. The use of automated meteorological measurements, analyzers of the quality of water flows from fields, measurement of the groundwater level, the use of georadar and other measuring instruments in the mode of monitoring and fixing the geographic coordinates of a research site according to the established program allow increasing labor productivity and obtaining more reliable survey indicators. Deciphering aerial photographs obtained in various light ranges by unmanned aerial vehicles, as well as information from satellites, allows us to obtain the required data on the state of farmland, including those out of use. In recent years, satellite imagery has been widely used for remote sensing of farmed land. However, such a source has a number of significant disadvantages associated with the high cost of images, limited opportunities for obtaining them at a given time and with the required frequency, as well as with an error caused by weather conditions, clouds and haze [15, 16]. In this regard, the use of radio-controlled unmanned aerial vehicles (UAVs) for imaging is more informative and reliable. The main advantage of UAVs is the high resolution with the simplicity of the imaging equipment and the optimal ratio between the quality of data and their cost, especially when filming not only in visible, but also in infrared ranges. For a comprehensive assessment of agricultural lands out of use, according to the AFI specialists, it is advisable to use an automated flying machine of the "copter" type, which has demonstrated higher efficiency and coverage of a wider range of tasks. New technologies make it possible to obtain high-precision digital elevation models, which cannot be done using traditional methods. It is also advisable to note the economic side of this problem. The use of an automated system significantly reduces the time spent on surveying overgrown lands, and also avoids significant labour costs associated with visual inspection.
of these fields [13-17]. Such methods based on the acquisition and processing of digital images have a number of important advantages:

- images can be easily archived, thus saving the maximum amount of data for further analysis of changes;
- allow you to keep records, and carry out inventory and classification of land with the construction of specialized agricultural plans and maps;
- obtaining aerial photographs of a given territory with specified parameters.

3. Results and Discussion

Survey of lands taken out of agricultural turnover using a UAV according to the current methods makes it possible to determine the degree of overgrowing of fields with tree and shrub vegetation and its density, tree species and thickness of trunks from the images, comparing them with a photograph of a model site overgrown with similar vegetation. It is also possible to calculate the volume of the aboveground part of trees, issue recommendations for mechanized harvesting and disposal; and determine the amount of uprooting (removal) of stumps, roots, and stones and recommend ways to remove them from the fields.

On drained reclaimed lands, local malfunctions of the reclamation system are determined, including water intakes, transport canals and other hydraulic structures. The coordinates of wet ground locations and their areas are calculated, recommendations are issued for troubleshooting and using the faulty reclaimed area. The geometric dimensions of channels and the volumes of bottom sediments are determined using a digital terrain model. The profile of the bottom and transverse dimensions of a channel are compiled, and the volumetric indicators of the repair of a faulty channel are calculated. After carrying out technical work on lands newly taken into agricultural turnover, liming must be carried out. It is known that liming of acidic soils is the most important method of increasing soil fertility and the effective use of mineral fertilizers. Long-term international experience and practice of agriculture testify to the constant acidification of soils as a result of the use of mineral fertilizers, root exudates, acid rains, as well as various biochemical processes occurring in soils [3, 4, 13-17]. They are also observed to be washed out of the soil root layer as a result of heavy rains with a leaching type of water regime typical for the entire territory of North-West Russia. There is no alternative to liming. By neutralizing excess acidity in soils, lime ameliorants increase the utilization rates of mineral fertilizers. The ecological situation is improving. The conditions for the soil biota are being optimized. Pathogenic fungal microflora is replaced by bacterial microflora. The number of phosphate-mobilizing bacteria, nitrogen fixators, and cellulose-decomposing microorganisms is increasing. A geochemical barrier to the washout of movable elements is provided. The removal of nutrients into water bodies decreases. It should be remembered that the utilization rates of nitrogen from fertilizers, and, consequently, their payback on strongly acidic soils are 1.4-2.7 times lower than on weakly acidic and neutral ones. With unsystematic application of phosphorus fertilizers on strongly acidic soils, their utilization rates are only 1.7-2.0%. On soils with a favourable reaction it is 10-15%, and with local application, 30%. It is known that liming significantly changes the properties of the soil absorbing complex. Under the influence of lime, the soil absorption capacity significantly increases, and this increase persists for many years. Soil calcareous particles become centers of structural aggregates thus contributing to the formation of a granular water-resistant structure. Calcium and magnesium are among the essential elements for plant life. However, lime is usually referred to as indirect fertilizer, since it is mainly applied to soil not as a source of nutrition for plants, but as a means of reducing soil acidity due to the presence of cations of aluminum, manganese, iron and hydrogen. It is known that cereal crops remove 20-40 kg of CaO annually; peas, vetch, flax, 40-60 kg; potatoes, sugar beets, corn, 60-120 kg; clover, alfalfa, sunflower 120-250 kg; and cabbage, 300-500 kg. This is a useful (productive) takeaway. However, unproductive losses of lime in most cases exceed the useful removal. The rate of interaction of lime fertilizers with soil and the duration of their action to a large extent depend on the chemical properties of lime and its granulometric composition. Limestones used to make limestone flour vary greatly in solubility depending on the bulk density. Therefore, depending
on the composition and structure of limestone materials, the requirements for the grinding fineness
should be different. The most stringent requirements should be imposed on lime materials in silicate
form which are less soluble. It has been proven that relatively large particles, with a diameter of more
than 3 mm are not "ballast", as previously thought, although they interact with soil much more slowly
than small particles. For the soil acidity level to be kept relatively constant over time, lime materials
must contain a wide range of particles of various sizes. The change in the soil reaction largely depends
on the dose of lime and the buffer properties of soil, which are determined by the content of organic
and mineral colloids. To shift the reaction in light soils, much less lime is required than to obtain the
same result in heavy soils.

One of the most important tasks in increasing the provision of agriculture with lime fertilizers at a
lower cost is the wider use of local carbonate materials. The use of those for liming has been known
for a long time and proven by practical and scientific experience of many countries. By the end of the
20th century, local materials accounted for no more than 14% of the total volume of lime fertilizers;
meanwhile, their reserves were huge and at that time amounted to about 700 million tons. In 34
regions, building material manufacturers alone produced 20.7 million tons of carbonate waste
annually; of those 8.9 million tons were used for various purposes. Taking into account the waste in
dumps of these enterprises, there was a possibility of producing 12-15 million tons of ameliorants
annually. The use of such ameliorants would allow solving the urgent problem of waste recycling.
This would reduce the area used for their storage, as well as provide agricultural producers with cheap
lime materials located geographically close to consumers. Another very important and rather cheap
source of replenishment of natural lime materials is industrial waste, which includes some types of
slag, sludge, shale ash, brown coal, waste chalk, lime-dolomite waste, defecates, etc. It is known that
most industrial waste does not require any complex preparation for use as a lime fertilizer. Most often,
it is sufficient to separate the larger particles from the bulk of waste through a sieve with holes 3-5 mm
in diameter. Some waste can be used for liming even without sifting. Many slags and ashes actively
interact with soil; therefore, they are significantly better than natural carbonates, and the admixtures of
trace elements contained in them often have a positive effect on the growth and development of
agricultural crops [3, 4]. Studies allow us to recommend liming with magnesium-containing open-
hearth slags on soils with a pronounced magnesium deficiency, which, when applied with high rates of
mineral fertilizers, provide a more balanced nutrition of agricultural crops and are more efficient than
liming. The use of industrial waste containing magnesium not only increases the yield of cultivated
crops, but also improves its quality. The contents of sugars in tomatoes, starch in potatoes, fat in oil
seeds, and some vitamins (A and C) in various plants increase. When using peat ash for liming, it
should be borne in mind that the ash of lowland and transitional peats is more effective in compa-
rison with the ash of high-moor analogs [3, 4].

Since 2013, in the Leningrad Region, we have been working on the introduction of an improved
technology for liming acidic soils with raw milled dolomite flour of coarse grinding taking into
account various levels of soil acidity. The Agrophysical Research Institute is actively involved in
creation of software and hardware systems for precision farming together with manufacturers of
agricultural machinery and electronics not only in Russia, but also abroad. As an example, let us
consider a hardware and software complex based on the RMU-8000 machine for the differentiated
application of lime ameliorants and other agrochemicals. The main task of the complex is introduction
of lime materials and solid mineral fertilizers into agricultural fields. The complex can operate both in
the usual mode (continuous, the same dose), and in the mode of "precision farming", in a differentiated
manner.

To work in the "precision farming" system, it is necessary to first conduct an agrochemical survey
of agricultural fields with a topographic reference and create, on the basis of the obtained laboratory
data, "task maps" that will be used by on-board systems of the complex in the field. The complex is a
joint development of the Agrophysical Research Institute (Russia), the Shchuchin Repair Plant
(Belarus) and the Gustrov firm (Germany). The complex is made according to the latest technologies
using high quality materials. The latest developments in the field of electronics, control and
monitoring equipment, and software are used [13-17]. The complex is a semi-trailed distributor of mineral fertilizers RMU-8000 equipped with on-board electronics, and on-board and office software. It can also be manufactured on the basis of a Kamaz vehicle or other appropriate equipment.

4. Conclusion
Taking into account the experience of our colleagues in Russia and abroad, and our own experience, it can be argued that the introduction of precision farming, the core of which is primarily information technology, will give a powerful impetus for the development of crop production in our country, transfer the industry to a qualitatively new level of production, and increase attractiveness of the industry for young workers. This requires the conditions for effective implementation of resource-saving technologies in agricultural production: the creation of a domestic physical industry for young workers. This requires the conditions for effective implementation of resource-saving technologies in agricultural production: the creation of a domestic physical industry for young workers. This requires the conditions for effective implementation of resource-saving technologies in agricultural production: the creation of a domestic physical industry for young workers. This requires the conditions for effective implementation of resource-saving technologies in agricultural production: the creation of a domestic physical industry for young workers.

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