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Resource-Saving Farming Systems In The Southeast Of Kazakhstan

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Abstract

The issues of improving the mechanisms for land management have now acquired a special relevance.These mechanisms should fully meet the economic, social and agroecological conditions and contribute to an increase in the productivity of agricultural land and the preservation of its fertility.As a result of a soil landscape survey in the subzone of dark and light chestnut soils in the southeast of Kazakhstan,soil landscape maps were compiled and technologies for adapting agricultural crops to agroecological groups of lands were developed. At the same time, on the sloping lands of the southern and western exposures, the increase in the humus content of light chestnut soils was more effectively influenced by flat-cut tillage, which provided a reduction in soil washout by 3...4 t/ha, compared with plowing.The use of zero and minimum tillage technologies contributed to the preservation and improvement of soil fertility and a significant increase in the efficiency of agriculture.Based on the results of remote diagnostics of the relationship between the chlorophyll content in plants and grain yield, the calculation of the doses of mineral fertilizers in the precision farming system was determined.

Key words: adaptive-landscape, zero, minimal, remote, probing, differentiated

Introduction

Because of irrational use of land in agricultural production, the annual loss of humus in agriculture in Kazakhstan is 0.5...1.5 t/ha. Currently, about 75% of the territories of the Republic of Kazakhstanare subject to an increased risk of desertification, 14% of pastures (more than 15 million hectares) have reached an extreme degree of degradation. More than 30.5 million hectares are subject to wind and water erosion (54% of these territories are located in the southern regions of the country). A high danger to the soil is a systematic violation of technologies for growing crops [1].

According to the monitoring of the main soil types in Kazakhstan that was carried out for the period 2007-2016, The Republican Scientific and Methodological Center of the Agrochemical Service showed that in the area of 24753.39 thousand hectares, soils with a low humus content occupied 76.12%, with average content - 22.76% and a with high one - 1.12%. In the context of regions, the supply of humus to soils also differs. In the southern regions of the republic, under irrigation conditions, 98% of soils have a low (less than 4%) humus content. In the northern regions of the republic, on non-irrigated lands, soils with a low humus content occupied 70.9%, lands with an average humus content occupied 27.5%. A similar trend was noted for the content of mobile forms of nitrogen and phosphorus, and as for exchangeable potassium, all soils of Kazakhstan are highly saturated [2].

The above circumstances and the aggravated ecological contradictions cause the need to intensify research on the optimization of farming systems not only in relation to specific natural conditions, but also to modern production relations. In such a situation, the existing zonal farming systems do not meet the modern requirements of farming.

The transition to adaptive landscape farming systems will contribute to the maximum differentiation of farming, depending on natural conditions. Adaptive landscape also includes removal of low-yield lands from arable land, intensification of agriculture with the priority of environmental factors, contour and reclamation of the territory depending on the terrain, carrying out a set of reclamation measures, the use of integrated systems of plant protection, fertilizers, soil cultivation, integration of all forms of management into the general system of agriculture, acceptable for the elementary geochemical landscape [3]. An adaptive landscape farming system is a system of land use for a specific agroecological group, focused on the production of goods of economically and ecologically determined quantity and quality in accordance with social (market) needs, natural and production resources, ensuring the sustainability of the agricultural landscape and the reproduction of soil fertility [4].

This approach will slow down and stop the processes of soil degradation, significantly increasing labor productivity in domestic crop production while reducing costs, creating a scientifically grounded basis for the functioning of agricultural production and human social well-being [5].

The agricultural analysts have long studied the issues of introducing energy and resource-saving technologies. In view of the global problems, resource conservation of the agro-industrial complex in the world plays a key role as an effective means of accelerating the pace of production and increasing labor productivity [6].

Resource saving is understood as a set of measures for the economical use of raw and stock materials, fuel, electricity, labor resources in the production and regulated use of technological means for their intended purpose.

One of the ways for rational use of land resources in agriculture is the technology of the so-called “minimum” and “zero” tillage. This is an economic system for the development of crop production, in which the optimization of production processes is of key importance. As a result, the plant growing industry becomes predictable, manageable and economically viable [7].

One of the basic elements of resource-saving technologies in agriculture is “precision agriculture, that is to say, crop productivity management taking into account the intra-field variability of the plant habitat. Relatively speaking, this is the optimal control for each square meter of the field. The purpose of such management is to maximize profits while optimizing agricultural production, saving economic and natural resources. This opens up real opportunities for the production of quality products and the preservation of the environment [8].

This approach, as international experience shows, provides a much greater economic effect and, which is more important, helps to increase the reproduction of soil fertility and the level of ecological purity of agricultural products. For example, a farmer from Germany, when introducing elements of precision farming, achieved an increase in yield by 30% while reducing the cost of mineral fertilizers by 30% and for inhibitors by 50% [9].

Consequently, at the present stage of the agriculture development in the foreseeable future, the degree of food security, the health of the population and the level of the life quality are largely determined by the latest developments in the field of alternative agriculture, the preservation of natural resources and, first of all, land as the main means of production, which predetermines the need for transition to conservation agriculture, including the following priority areas in the Republic of Kazakhstan:

- formation of scientific foundations for adaptive landscape farming systems and their use;
- improvement of technologies for resource-saving agriculture (minimum and zero tillage);
- development of precision farming technologies, including the global positioning system (GPS), Yield Monitor Technologies (YMT) and Earth remote sensing (ERS).

Materials and methods

The development and design of the adaptive landscape farming system (ALFS) was carried out in 2010-2016 on the territory of LLP “Bayserke-Agro” at theTalgar district of Almaty region. This region is typical in terms ofagro-ecological conditions for farmlands, located on the sloping foothill plain in the north-western direction of the Iliy Alatau.

Electronic maps reflecting agroecological factors taken into account in the design of the ALFS were compiled on the basis of soil landscape mapping at a scale of 1:50.000. In the process of mapping, we used a digitized topographic base of the same scale of 1:50.000, satellite images of different resolutions, materials of past large-scale soil surveys, land management plans, and fund materials.

For resource-saving agriculture, we studied the adaptability of different varieties of winter wheat to the conditions of the region in the subzone of dark chestnut soils and chernozems of the high-mountainous zone of the southeastern Kazakhstan (2010-2016). Studies were carried out on erosional agrolandschafts in the subzone of light chestnut rainfed soils, in elementary areas, where the adaptability of plowing and flat-cut soil tillage was assessed depending on the exposure of slopes. We studied the effect of minimal and zero tillage on fertility in the semi-secured rainfed zone on light chestnut soils, along with the traditional methods of basic tillage.

Studies on the system of precision farming based on the intra-field variation and plants in terms of the nutrients’ content were carried out on irrigated light chestnut soils in 2010-2016 in the framework of the long-term multifactorial experimentby the Kazakh Research Institute of Agriculture and Plant Growing. The scheme of the experiment was a special sample of 1/8 part of the full factorial experiment (4x4x4x4), including 32 variants in duplicate and placed on an area in the form of a quasi-Latin square, under the conditionsof the influence by increasing norms of nitrogen, phosphorus and potassium fertilizers and manure on the agrochemical parameters of soil grain yield of winter wheat.

Results

Based on the grouping of soil cover structures, combined according to the parameters of soil combinations that have a specific agronomic value,an agroecological assessment of lands was carried out. At the same time, we distinguished automorphic elementary soil structure (ESS), automorphic saline ESS, semi-hydromorphic-zonal ESS, semi-hydromorphic ESS, semi-hydromorphic salineESS, hydromorphic meadowESS, hydromorphic meadow salineESS.

The carried-out soil and landscape survey and the electronic maps of arable lands of the model economy, compiled on its basis, provided information on the landscape differentiation: geomorphological, lithological and hydrogeological conditions, soil cover structure, particle size distribution, erosion hazard, salinity and soil hydromorphism. In addition, agroecological groups of lands have been identified according to the leading agroecological factors that determine the direction of their agricultural use (moisture supply, erosion, waterlogging, salinity, etc.). GIS of agroecological land assessment was developed (we created a set of the electronic maps) according to the manifestation degree of the above-mentioned factors and related limiting factors, as well as land types by categories of soil cover microstructures (microcombinations), including elementary soil areas, complexes, spots and microtasks (Figure 1).

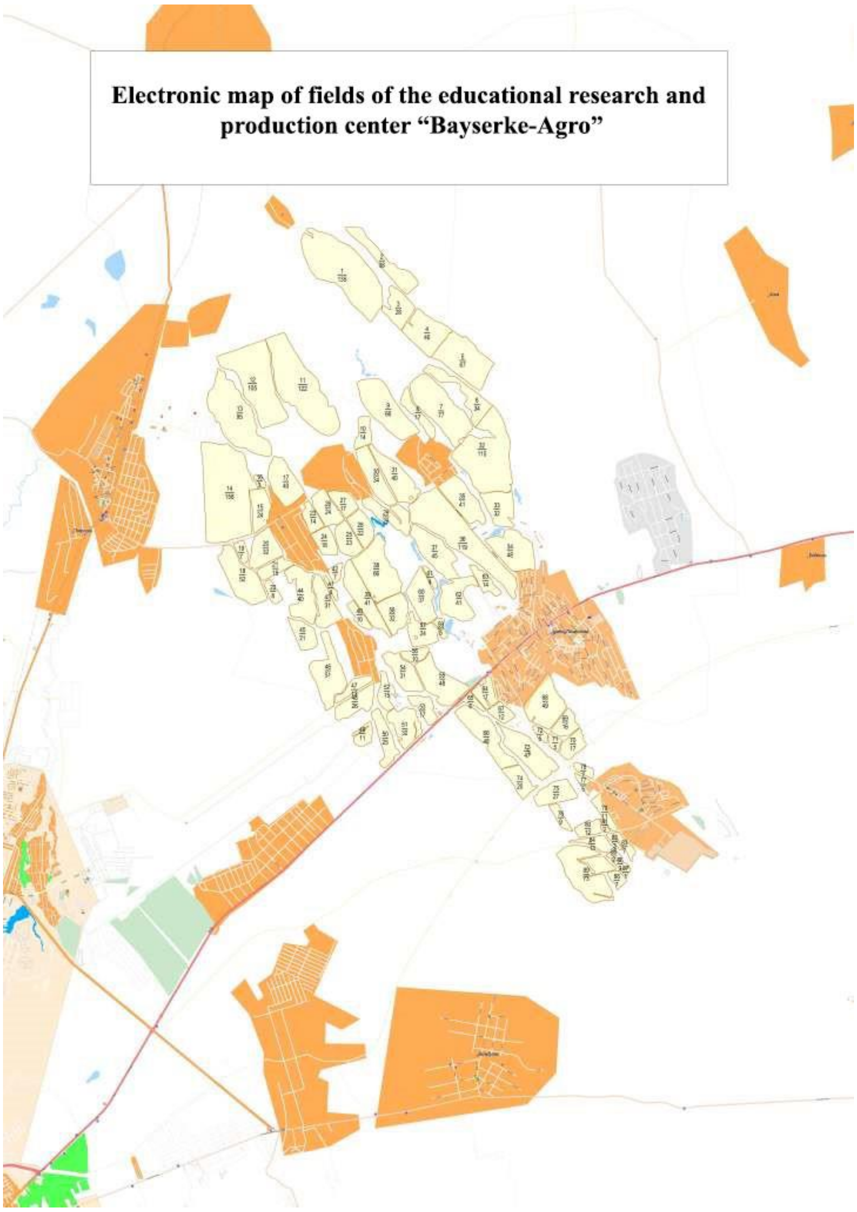

Figure 1. Electronic map of fields of the educational research and production center "Bayserke-Agro"

The results of the study on the adaptation of various varieties of winter wheat in the conditions of erosional agrolandscapes of the alpine zone of the Almaty region on mountain chernozems and dark chestnut soils showed that the Bogarnaya 56 variety forms an average yield of 1.9 t/ha, while the Steklovidnaya 24 and NAZ varieties - 1...2.3 t/ha, or by 0.21...0.40 t/ha more, which indicates their higher adaptability.

According to the result of thevarious soil treatments' adaptation on the slopes of the southern and western exposures, it was revealed that the flat-cut tillage of light chestnut soils turned out to be more adaptive, providing a decrease in their washout by 3...4 t/ha and an increase in the content of humus and nutrients by 0.20...0, 35 t/ha compared to plowing (Figure 2).

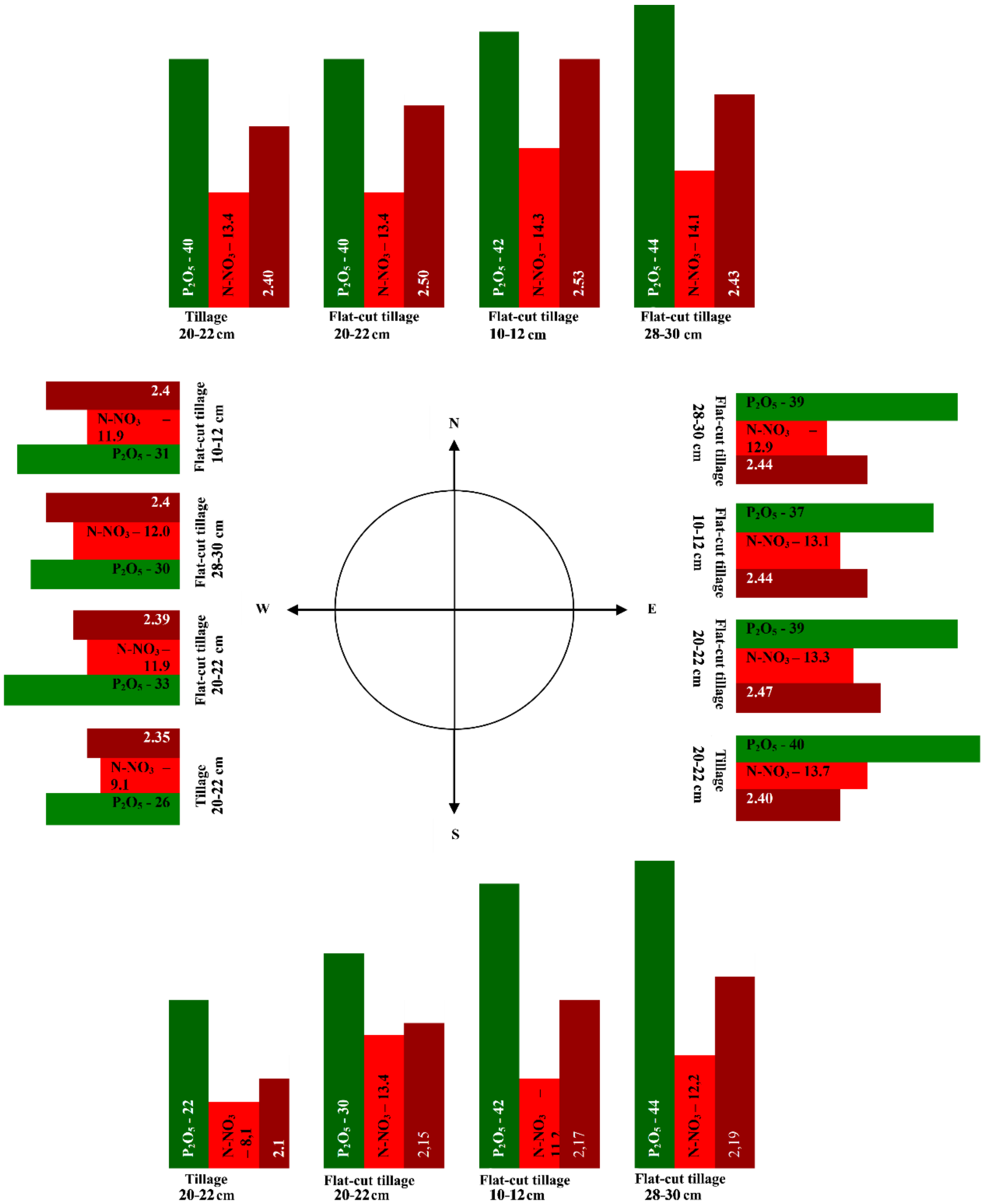

Figure 2. Differentiation of the main tillage types depending on the exposure of the slopes

Studies that were carried out in the southeast of Kazakhstan on minimum and zero tillage have shown that they lead to the creation of a heterogeneous (with different quality) arable layer in terms of the content of organic residues with a predominant accumulation of plant mass in the upper layer. So, with the usage of flat-cut tillageon the depth of 20-22 cm, on average for 3 years, the content of organic residues in the layer of 0-30 cm was 149.2 cwt/ha, then with tillageon 6-8 cmthe content was 157.6 cwt/ha, and the highest indicatorswerewithdirect seeding (172.8 kg/ha) (Table 1).

Table 1. The content of root and plant residues under the winter wheat, depending on the methods of soil cultivation (cwt/ha)

Methods of soil cultivation	Years			Medium value, cwt/ha
	2010	2011	2012	
Tillage 20-22 cm (control)	124.5	110.5	119.0	118.0
Flat-cut tillage at 20-22 cm	157.5	148.0	142.0	149.2
Flat-cut tillage at 10-12 cm	158.7	150.7	140.0	149.8
Flat-cut tillage at 6-8 cm	160.0	160.8	152.0	157.6
Direct seeding on stubble	175.0	156.5	178.0	172.8
HCP_{05}				6.8

Thus, in the conditions of semi-supplied rainfed soils of the southeastern Kazakhstan, the creation of a plow layer, which is heterogeneous in terms of the organic residues content, along with an increase in the anti-erosion resistance of the soil surface, also provides a mulching role to improve the preservation of moisture, that is to say, in general, they contribute to the optimization of soil fertility.

In the practice of precision farming, an electronic map of the field yield is used for information calculations to determine the rates of applied fertilizers. This map makes it possible to analyze the heterogeneity of productivity and to determinethe degree of the production process' provision with the necessary elements.

As a result of research, based on the yield data of the stationary site of the Kazakh Research Institute of Agriculture and Crop Production, a map of the yield of the experimental fields was compiled, where the variability of the stationary site is clearly traced (Figure 3).

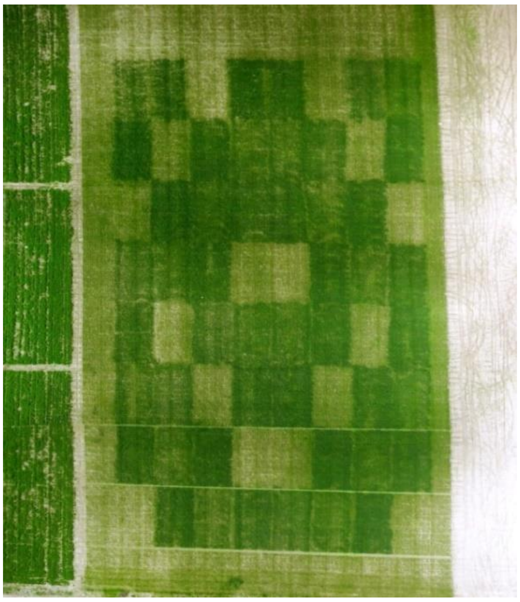

Figure 3. General view of the experimentplots with winter wheat in the tillering phase (picture from a hexocopter)

Plots without nitrogen fertilizers (there are 16 of them), as well as options with applied nitrogen fertilizers, are especially distinguished. The highlighted diversity of the experimental plot contributed to the formation of different levels of grain yield of winter wheat, depending on the application of increasing norms of nitrogen fertilizers against the background of the phosphorus-potassium action and the aftereffect of organic fertilizers.

The spectral reflectivity of green vegetation, which is a characteristic feature, was used for remote diagnostics of the plants' supply with nutrients. Moreover, in the visible wavelength range, the pigmentation affects the spectral characteristics of plants, especially chlorophyll (Figure 4).

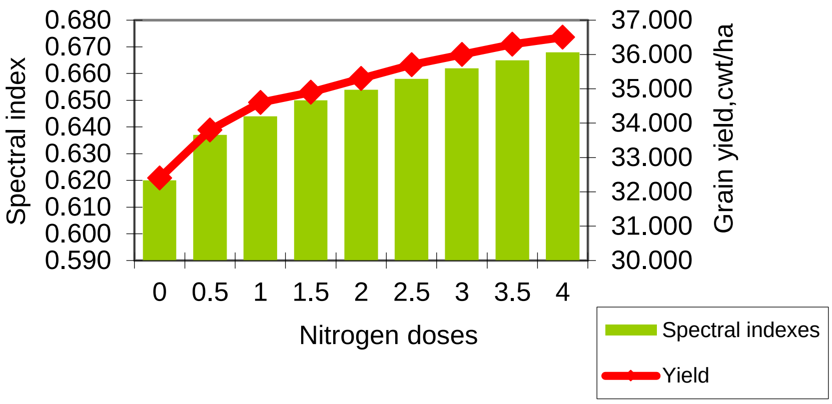

Figure 4. Spectral indexes and grain yield of winter wheat depending on the dose of nitrogen fertilizers

Table 2 shows the relationship between the content of nitrogen and chlorophyll in plants and grain yield, as well as the indicators of the plants' supply with nitrogen and the indices of "greenness" in the critical period of feeding.

Table 2. Relationship between the indicators of the winter wheat plants' provision with nitrogen and chlorophyll for different levels of grain yield

Indicators	Grain yield, t/ha					
	<3.0	3.1...3.5	3.6...4.0	4.1...4.5	4.6...5.0	>5.0
Total nitrogen, %	<2.6	2.7...3.0	3.1...3.3	3.4...3.7	3.8...4.0	>4.0
Chlorophyll, mg/g	<1.8	1.9...2.3	2.3...2.7	2.8...3.1	3.2...3.5	>3.5

The obtained data formed the basis for determining the calculation of differentiated doses of mineral fertilizers in the precision farming system.

Discussions

The development and successful implementation of an adaptive landscape farming system in the southeast of Kazakhstan is a complex procedure becausewe have to use a wide variety of techniques in conditions of changing weather, different soils and different reliefs. The term “landscape” in this context means that the land is developed in a specific category of agrolandscape, or in other words, in agroecological groups of lands. The obtained results using this approach to the agroecological assessment of agricultural landscapes are in greatcompliance with the studies’ results ofRussian scientists, both in terms of their main agroecological features, and in terms of the applied assessment criteria[10-12].

Adaptation of various soil treatments and varieties of agricultural crops to various agroecological groups of lands for adaptive landscape farming provide an increase in soil fertilityby 7...25%, crop yields by 30...60%, and with intensification of cultivation - by 64...105%. This indicates, in general, a significant advantage of adaptive landscape farming, in comparison with the adopted zonal systems, and the need for differentiation of land use [13-16]. According to the results of our research, the use of various methods for soil cultivation and varieties of agricultural crops, based on the adaptive landscape approach, provides a significant increase in the productivity of arable land.

In recent years, the areas for agricultural crops, cultivated using resource-saving technologies, have been constantly expanding. In the United States, direct seeding is used on 26.6 million hectares, in Canada - on 13.5 million hectares, in Brazil - on 25 million hectares, in Argentina - on 19 million hectares, in Australia - on 12 million hectares, in Kazakhstan - on 1.2 million hectares [17-18]. With surface tillage to a depth of 5...7 cm (with the so-called Mini-Till), natural drains formed by the decaying remains of the root system and the tubules formed by earthworms are preserved. The system of natural drains and canals makes the soil more loose to a great depth, much deeper than it happens during plowing. This system is capable of letting air and moisture into the soil mass [19-20].

The use of resource-saving technologies in the southeast of Kazakhstan helped to preserve soil fertility, significantly reducing production costs and increasing the efficiency of agriculture in general. At the same time, the task of increasing the potential soil fertility is achieved by creating a biologically active mulch layer due to the use of fruit crops and crop residues in crop rotation. However, it is impossible to completely copy the foreign experience of using minimal and especially zero tillage due to the specific agro-ecological conditions of each region.

According to N.K. Tynybaev and E.K. Zhasipbekov, the implementation of minimal, and zero tillage is possible within the framework of intensive agricultural technologies, with sufficient supply of fertilizers, plant protection products in optimal crop rotations and with a high crop production culture[21].

In recent years, precision farming systems have become increasingly common in agriculture. This is an innovative type of industry management, which is the highest form of adaptive landscape farming based on science-intensive agricultural technologies with a high degree of manufacturability [22-23].

In the Midwest of the United States, precision (coordinate) farming is associated not with the concept of sustainable farming, but with the mainstream in agribusiness, which seeks to maximize profits by making costs only for fertilizing those parts of the field where fertilizers are really needed. Following these ideas, agricultural producers use technologies of variable or differentiated fertilization in those areas of the field that are identified using GPS and where the need for a certain rate of fertilizers is identified by an agricultural technologist using agrochemical survey and yield maps. Therefore, in some areas of the field, the rate of application or spraying becomes less than the average, there is a redistribution of fertilizers in favor of areas where the rate should be higher, and, thereby, the fertilization is optimized [24-25].

In our studies, the differentiated application of increasing norms of nitrogen fertilizers provided an improvement in the quality of winter wheat grain. When the content of crude protein is 14.0% in the control variant without fertilizers, the application of 30-180 kg/ha fertilization led to an increase in the content of crude protein in grain by 0.8-1.9%.

Conclusions

1. On the basis of the conducted soil and landscape survey of the LLP “Bayserke-Agro” territory, agroecological groups of lands were identified according to the leading agroecological factors that determine the direction of their agricultural use (moisture supply, erosion, waterlogging, salinity, etc.), according to the degree of these factors’ manifestationand by concomitant limiting factors.We also identified land types by soil cover microstructure categories.

2. We established that on the slopes of the southern and western exposures, the flat-cut tillage of light chestnut soils is more adaptive, providing a decrease in their washout by 3-4 t/ha and an increase in the content of humus and nutrients in comparison with plowing.

3. The use of minimum and zero tillage technology in the southeast of Kazakhstan contributed to the improvement of soil fertility, reduced production costs and significantly increased the efficiency of agriculture.

4. It was revealed that the spectral reflectivity of green vegetation, in particular chlorophyll, can be used for remote diagnostics of plants based on the supply of nutrients.

In general, the rational use of land resources, conservation and reproduction of soil fertility are achieved through the use of a modern system of adaptive landscape, resource-saving and precision farming.

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