Prospects for the development of adaptive landscape farming systems in Russia

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Abstract. The achievements of adaptive landscape agriculture systems (ALAS) were considered as an expression of a new, biospheric paradigm of nature management. ALAS are confined to various agroecological land groups (upland, erosive, hydromorphic, saline, etc.). Within the groups, there are land types for which agricultural technologies of various intensification levels are being developed. The ALAS design tools include a register of land types, a register of crop varieties, and a register of agrotechnologies. The development of ALAS projects for agricultural enterprises is carried out in AgroGIS based on soil and landscape mapping materials based on agroecological typology and landscape-ecological classification of lands. ALAS are formed based on the results of multifactorial field experiments that establish systemic links between agriculture elements and landscape-ecological conditions. The ALAS development is associated with the deepening of landscape differentiation and further with the design of agricultural landscapes (cultivated lands, livestock, water, forestry, residential ones) in the territory ecological framework system. The methodology and tools of their design based on the transformation of ecological functions of the landscape into socio-economic ones are proposed.

1. Introduction
Modern agriculture in Russia and neighboring countries in the post-Soviet space is undergoing significant transformations under the influence of changed socio-economic conditions. Earlier, this process began in connection with overcoming the adverse environmental consequences of economic activity. Since 1980, extensive work has been underway on the formation and development of zonal farming systems in relation to various natural and agricultural zones and provinces. Methodological manuals in the form of extensive monographs have been developed for most regions. The impetus for this was the experience of the agriculture soil protection system development, developed in Kazakhstan under the leadership of Academician A.I. Baraev [1].

In 1985, a campaign was launched to develop intensive agricultural technologies borrowed from Western European countries. By this time, the permanent global agrotechnological revolution (green - agrochemical – informatization), which began in the 40-50s in South America thanks to the creation of intensive wheat varieties by N. Borlaug, had steadily grown.

The experience of mastering intensive wheat cultivation technologies in Russia on an area of about 5 million hectares in 1986-1990 showed high results in yield and technological quality of products. Nevertheless, due to poor campaign preparation and imperfection of technologies for the use of agrochemicals, their contamination of crops and the environment was significantly manifested. This caused a public outcry, and the campaign was terminated. In Western European countries, these
shortcomings were largely overcome in the same years by improving agricultural technologies.

By the end of the XX century, the ecological situation in the world was significantly complicated both due to the costs of agricultural intensification in the form of landscape pollution, and as a result of extensive agriculture in the form of soil depletion and degradation, not to mention the consequences of hydraulic reclamation and industrial activities. The consequences of regional environmental disasters such as the Aral Sea and the threat of a global environmental catastrophe prompted the change of the nature-based paradigm of nature management to the biosphere one, which was originally presented in the form of the sustainable development ideology at the UN Conference in 1992. In the same year, the Resolution of the session of the Russian Agricultural Academy determined the course for the development of the Dokuchaev land use methodology and the creation of sustainable agricultural landscapes. This call immediately provoked an active response in the form of a number of concepts that emerged as a result of rethinking and development of zonal farming systems: "adaptive crop production" [2], "contour-reclamation agriculture" [3], ecological-landscape agriculture [4], contour [5,6], adaptive landscape agriculture [7] and a number of others that reflected various aspects of agriculture.

The methodology of adaptive landscape farming based on the results of long-term field experiments in various landscapes (upland, erosive, saline, semi-hydromorphic) of the forest-steppe and steppe zones of Siberia and Kazakhstan has received the fullest development [7].

2. Materials and Methods

A fundamentally new approach to the formation of adaptive landscape farming systems (ALFS), along with their adherence to certain agroecological land groups, has established their compliance with market conditions, biological and technological requirements of agricultural crops, certain levels of production intensification, and economic patterns. In accordance with these conditions, the classification of ALFS and agroecological land typification was developed, including agroecological groups for which ALFS are being developed; land types for which crop rotations are formed; types with which agrotechnologies are associated [7].

Identification of land groups, types, and species was carried out based on landscape and ecological classifications of lands that were developed for natural-agricultural provinces in accordance with natural-agricultural zoning scheme [8]. The totality of ALFS within the province was defined as a zonal-provincial agrocomplex.

For the formation of ALFS, a new system of landscape and ecological design was required instead of the traditional land management, which was carried out using the simplest agro-industrial grouping of soils. Initially, this work was carried out on the basis of paper soil and landscape maps M:1:10000. The first ALFS projects developed by us for the Mikhailovskoye Instructional Farm of the Moscow Agricultural Academy named after K.A. Timiryazev and the Gatchina Experimental Production Facilities of the Leningrad Research Institute of Agriculture on paper were cumbersome and expensive. Subsequent projects, starting in 2004, are carried out on a digital basis [9], that is, AgroGIS, which is a set of electronic maps and cartograms: relief forms, steepness and exposure of slopes, soil-forming rocks, depth and quality of soil and groundwater, microstructures of soil cover, granulometric composition of soils, hydromorphism, salinity, soil salinity, humus content, etc. By overlapping of these layers, a map of agroecological groups and types of land is formed.

The ALFS design begins with the creation of an electronic map of the suitability of land types for crops of market and economic interest. It is developed by comparing indicators of ecological requirements of agricultural crops with agroecological indicators of land. The assessment is carried out according to 6 suitability categories. Further, by overlapping maps of land suitability for various crops with the help of the Panorama AGRO program, common land plots are obtained for the cultivation of certain crops and thus crop rotation fields are formed. Systems of tillage, fertilizers, and plant protection are being developed within crop rotation fields, considering agroecological indicators of the land.

The most difficult task of ALFS designing is the organization of the territory, especially under the
conditions of surface runoff, and the development of anti-erosion measures. The first methodological guide for ALFS development and design at the regional level was published by us for the Novosibirsk region [10].

ALFS adaptation to different land types, levels of intensification, and economic structures is implemented through agrotechnology packages. According to the level of intensification, it was proposed to distinguish extensive, normal, and intensive agricultural technologies [9]. This proposal was not immediately accepted, but it has a special meaning. Extensive technologies of cultivation of agricultural crops without the use of mineral and organic fertilizers are still widespread. The depletion and degradation of soils and agricultural landscapes, especially marginal ones, are the consequences. In this regard, it seems appropriate to limit the use of erosive lands without protective measures.

Normal agricultural technologies are focused on ensuring a deficiency-free balance of plant nutrition elements and preventing soil degradation. They are soil-protective, if necessary, ameliorative. They use plastic varieties of grain crops in contrast to tolerant varieties in extensive agricultural technologies.

Intensive agrotechnologies are focused on the cultivation of intensive varieties to ensure optimal nutrition and protection of plants from harmful organisms and achieve maximum profit with high product quality and environmental safety. These technologies are implemented by controlling the production process of agricultural crops using precision technology and modern agrochemical tools. In the 90s, the processing of crops with technological solutions and other operations were carried out on a constant technological track. In the future, with the development of electronics and computer science, technological processes were controlled in GIS using remote methods of the earth surface sensing using GPS. Such intensive agricultural technologies are called precision ones, and the ALFS systems that include them are precision farming systems. The methodology for the formation of agrotechnology packages was implemented in the Federal Registers of Crop Production Technologies [11].

By 2005, there was a certain experience in ALFS designing with agrotechnology packages in farms of various regions, which was summarized by us in the form of an extensive methodological guide [12]. In the following years, a number of similar regional monographs were published. In general, the necessary scientific prerequisites for the ALFS development were created. They were implemented to one degree or another in farms of various regions, especially effectively in the Belgorod region [13].

3. Results and their discussion

Currently, the methodology of adaptive landscape farming is receiving new development, primarily in relation to territorial planning. Instead of regional monographs with methodological recommendations on the development of farming systems, we have started the development of regional geoinformation systems for the integrated assessment of land, the ALFS design, and innovative agricultural technologies. They are created by integrating electronic topographic maps, soil-forming rocks, groundwater, soil cover in M:100000. Based on them, the scheme of natural and agricultural zoning (boundaries of natural and agricultural zones and provinces) is being clarified, a map of agroecological groups of lands is being developed and the main agroecological land types are being identified. Then, based on many years of multifactorial field experiments and generalization of practical experience, farming models with agrotechnology packages are developed. The tools of their design are formalized in the form of registers of land types, registers of varieties of agricultural crops, and regional registers of agricultural technologies. Registers of varieties are being developed in relation to natural and agricultural provinces. For this purpose, agroecological passports of varieties are used, which reflect the main biological features, agroecological requirements, and bioproductive potential. Registers of land types are formed within agroecological land groups that differ in the main agroecological conditions that determine the directions of agricultural use and the choice of farming systems (upland, erosive, semi-hydromorphic, saline, alkaline, floodplain, etc.). Land types are distinguished by the totality of soil properties, features of micro- and mesorelief, features of soil-forming rocks that determine the choice of certain plant varieties, methods of soil use and reclamation, and, accordingly,
agrotechnologies. The diversity of agricultural technologies is reflected in their regional register, which is developed on the basis of experimental and production data generalization in relation to various levels of agriculture intensification. With an increase in intensification level, the number of conditions considered increases.

Large-scale development of ALFS is constrained by the uncertainty of agricultural scientific, technological, and innovation policy. Agrochemical nihilism manifests at various levels, various surrogates are promoted called "biological", "ecological", "bioecological", "ecological-biosphere" farming, etc. Nihilistic declarations in relation to mineral fertilizers lead to a dead end of extensive farming with a violation of the circulation of substances and subsequent soil degradation. Organic farming also needs to be differentiated from scientific farming. Its capabilities are greatly overestimated and go beyond the niche defined in adaptive landscape farming systems. There are obvious attempts to substitute the priorities of intensification and farming modernization by it.

Various extremes exist with regard to the use of mineral fertilizers. Business services for fertilizing "profitable" crops appeared on certain sections of fields under the name "precision farming" to maximize yield. It should be noted that such application of fertilizers with their optimal availability is advisable when using intensive agricultural technologies in ALFS in the expectation of maximum profit after the tasks of compensating for the deficiency of mineral nutrition of plants in crop rotations have been solved. These are the deficiency of phosphorus in fallow fields against the background of accumulated mineral nitrogen and moisture, the deficiency of mineral nitrogen created during the development of soil protection (minimal) tillage systems, etc. Mineral fertilizers are a system-forming factor of adaptive landscape farming, since they determine to one degree or another the choice of crop rotation, the proportion of complete fallow, the possibility of tillage minimizing, seed seeding rates, and product quality. Therefore, the payback of mineral fertilizers produced in ALFS reaches 10 kg of grain per 1 kg of active substance, that is, twice as high as the current payback in farms.

Minimization of soil tillage is developing under the protection of agrochemical agents. It received a powerful impetus with the creation of a soil protection farming system and is at a new stage of development, including periodic and permanent direct sowing, which is of great soil protection importance. As for energy saving, the saving of mechanical energy is often overlaid by the costs of chemical energy of fertilizers and pesticides to overcome the increasing weed infestation of crops and nitrogen deficiency. It is important to identify limiting agroecological conditions, especially soil densities, for direct sowing. The optimal solution for minimizing tillage, especially in complex erosive landscapes, is achieved precisely in adaptive landscape farming systems.

The most urgent task of ALFS development is the organization of their design by expanding the agrochemical service functions and the creation of research and innovation centers for the development of intensive agricultural technologies.

With all the achievements of adaptive landscape farming associated with the greening of technological processes, a more complete use of the biopotential of landscapes, the insufficiency of territory organization in terms of regulating energy and mass transfer, especially liquid, solid, and ion runoff and regulating the hydrogeological regime has manifested. Although these tasks were declared and developed, they could not be solved only within the field infrastructure, regardless of the geographical landscape. Thus, the problem of ALFS turned into a problem of designing agricultural landscapes, that is, field landscapes, then agricultural landscapes in general, including livestock, water management, agro-industrial, forestry, residential and others. At the same time, the problem of land ratio, especially natural and agricultural, has become more acute, which crystallizes into the ideology of ecological frameworks of the territory integrated with the field infrastructure.

The construction of agricultural landscapes means a directed change in their functions, that is, the transformation of ecological functions into socio-economic ones to one degree or another. Therefore, the mechanism of construction and design, accordingly, should be based on a sufficiently developed system of identification and evaluation of landscape functions and their classification. This process is closely related to the analysis of the landscape structure. We have proposed groupings of landscape ecological and socio-economic functions. Ecological functions are considered as a set of processes that
determine the development, conservation, sustainability, and evolution of ecosystems and the biosphere. Five groups of ecological functions with subgroups are distinguished. Most of them have quantitative expression, others require formalization and improvement of methods for their identification and evaluation. [14] In the process of mastering and using natural landscapes, a person brings a lot of social, industrial, and other functions that integrate with landscape ecological functions. The resulting functions aimed at satisfying human needs are called socio-economic ones. Some ecological functions of landscapes are used as socio-economic (aesthetic, recreational) without significant transformations. Part of the socio-economic functions (bioresource) is formed due to the partial withdrawal of bioproducts while preserving all the ecological functions of the landscape. In agricultural landscapes, the formation of socio-economic functions is associated with a significant transformation of ecological functions with varying degrees of conservation of ecological functions. For example, the biodiversity function is reduced during the agricultural development of the territory, but to a certain extent it is replenished by the creation of new plant species and varieties by human. The bioproduction function is transformed into an agrobiotechnological one. With extensive farming, all ecological functions associated with photosynthesis are significantly reduced. Their compensation can be achieved due to the function of regulating the circulation of substances (agrochemical), managing the regime of organic matter, meliorative, agrobiogeocenotic ones (formation of adaptive landscape farming systems, designing optimal agricultural landscapes). Due to land reclamation and other means, it is possible to form landscapes that are superior in productivity to natural ones. Thus, compensation of ecological functions that are lost in technogenic landscapes can be achieved to one degree or another.

Of particular importance is the formation of ecological frameworks of the territory integrated with the ecological infrastructure of agricultural landscapes (ecologically determined sizes of fields, their configuration, placement of fields and production sites, their connection with forest protection and reclamation measures, plant scenes, etc.). The ecological framework of the territory includes: basic reserves (nature reserves, wildlife sanctuaries, natural parks, forests of the first and second groups); ecological corridors connecting them (river valleys, strip forests on watersheds, green corridors of transport infrastructure, protective forest belts); buffer zones (water protection, sanitary protection zones, watershed protection zones); local elements (habitats of valuable species, entomological wildlife microsanctuaries, isolated territories with regulated nature management); territories of nature restoration (degraded farmland, ravine-beam complex). The principles and methodology of designing agricultural landscapes are described in the monograph [14].

As a tool for designing agricultural landscapes, the following is proposed: a system for assessing and grouping landscape ecological functions, structural and functional analysis of the landscape, identification and evaluation of landscape connections; justification and grouping of socio-economic landscape functions.

In this direction, the master's program "Agroecological assessment of lands and design of agricultural landscapes" has been developed and tested for ten years and educational literature has been offered.

4. Conclusions

Over the past thirty years, adaptive landscape farming systems have been developed and tested in Russia in the regions, corresponding to the biosphere paradigm of nature management and new economic relations. The distinctive features of ALFS are compliance with the biological requirements of plants, certain landscape and environmental conditions, market, levels of production intensification, economic structures, product quality requirements, and environmental safety conditions. They are formed as models of agriculture optimization based on the results of multifactorial field experiments, in which systemic connections of agriculture elements with environmental conditions are revealed. ALFS are implemented by packages of extensive, normal, and intensive agrotechnologies, which are developed for agroecological types of land using registers of land types, registers of varieties, and regional registers of agrotechnologies.
The design of ALFS and agrotechnologies is carried out based on the materials of soil-landscape mapping based on agroecological typology and landscape-ecological classification of lands.

Further development of adaptive landscape farming is represented in the form of designing agricultural landscapes (agricultural landscapes, livestock landscapes, water management, agroforestry, residential, recreational, etc.) in the system of the ecological framework of the territory. Algorithms and tools for their design are proposed.

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