Adaptive resource capacity management agricultural landscapes of Siberia for efficient cultivation grain crops

G L Utenkov¹, O A Ivanov², T E Ivanova² and A N Vlasenko¹

¹Siberian Federal Scientific Center of AgroBioTechnology, Russian Academy of Sciences, Krasnoobsk, Novosibirsk region, Russia
²Research Institute of Agrarian Problems of Khakasia, Abakan, Russia
e-mail: utenkov1951@mail.ru

Abstract. In the grain production of Siberia, not everything is provided safely. With a yield potential of 30 - 35 million tons, the actual grain production is 13 - 14 million tons. Cultivation of grain crops is energy intensive, extensive and ecologically unbalanced. The management of the productivity of agrocenoses is carried out by agricultural technologies. This management problem has not been solved even in modern precision farming systems. The purpose of the research is to increase the efficiency of grain crops cultivation by managing the resource potential based on agricultural technologies that take into account spatio-temporal changes in properties and the state of agricultural landscapes in Siberia. Research methods. Structural analysis and synthesis, mathematical modeling of mechanical and technological solutions and the integral indicator of agriculture. Main research results. Intensification is the main way to increase the efficiency of grain production, an analytical expression is proposed for the integral criterion of agriculture - the really possible value of their yield. For the management of agricultural technologies, a 4-level hierarchical concept with mechanical and technological temporary control actions is proposed: the upper level is strategic management. Developed adaptive-mobile field crop rotations, providing 2.72–3.09 MJ growth of the energy coefficient. For the arid regions of Siberia, the Research Institute of Applied Sciences of Khakasia proposed a surface irrigation technology. Provides an increase in labor productivity by 3-5 times, reduces the cost of 1 ton of hay by 3-4 times with an average yield of 5 t / ha; the second level is the management of a separate growing season; a furrow-band sowing was proposed, providing a 20 - 35% increase in yield; the third level is technological control in real time. An automatic flexible technological complex for the main tillage is proposed, which improves the quality of tillage and increases labor productivity by 15 - 20%; the fourth is the level of technological impact on the basis of scientific principles, taking into account the physical, mechanical and technological properties of the treatment object. Conclusions: 1) In the conditions of Siberia with its spatio-temporal changes in the properties and conditions of the soil cover, precise (digital) management of the resource potential of agricultural landscapes is required. 2) To increase the efficiency of grain crops cultivation, four mechanical and technological levels of control have been proposed.

1. Introduction
In the crop production of Siberia, grain crops are predominant, the area of cultivation of which reaches 60%. At the same time, Siberia accounts for 46% of oats produced in Russia, 17% of wheat and 15% of barley. However, over the past 30 years, yields and gross grain harvests have not changed significantly. On average, Siberia produces 13-14 million tons of grain per year with an annual harvest potential of 30-35 million tons [1]. It is believed [2] that the peculiarity of grain production in Siberia
at this stage is the almost complete exhaustion of extensive technologies and stabilization of their productivity at the level of 1.2 t/ha in the steppe zone, 1.5 t/ha in the southern forest-steppe, which does not correspond to the potential resources of the agricultural landscapes of the territory. Grain production in Siberia remains extensive, energy-intensive and ecologically unbalanced. An agricultural landscape is understood as a natural-territorial complex, the natural vegetation of which has been replaced by agrocenoses in the overwhelming part of it. It is characterized by ecological instability [3].

In general, grain production, regardless of the levels of intensification, is naturally accompanied by an increase in the total cost of obtaining an additional unit of production and, ultimately, an increase in unit costs and energy costs. The growth of unit costs and, accordingly, energy consumption, depending on the level of intensity, exceeds several times and even by an order of magnitude. Therefore, solving the problem of grain production per capita in the amount of 1 - 1.2 tons/person is not only a way, but also the basis for a prosperous future of Russia [4]. According to S.Yu. Glazyeva: "Outdated technological structures are burdened with excess capacity, which faces large-scale depreciation of capital. The continuity between the two modes consists in the application of technology based on the use of knowledge about elementary structures of matter, algorithms for processing and transmitting information obtained by fundamental science".

For agriculture in Siberia, heat and moisture resources are the least regulated factors in agriculture. The combination of agroecological requirements of crops and natural conditions of agricultural landscapes is carried out using various technology packages, including three levels of crop cultivation technologies: extensive, normal and intensive. At the same time, optimal technology implies high economic efficiency and environmental safety of production.

It is believed [5] that in the regional food security system, limited resources do not allow the production of all products to be concentrated in the most favorable conditions. This has a significant impact on the feasibility of specialization of subsystems of the agro-industrial complex of the region for the development of industries that are effective in these soil-climatic and economic conditions. Therefore, it is considered that it is not the magnitude of the energy impact that is important for natural systems, but the proper form of spatial energy distribution - the "architecture" of the energy impact.

The purpose of the research is to increase the efficiency of cultivation of grain crops by managing the resource potential based on agrotechnologies that take into account spatial and temporal changes in the properties and condition of agricultural landscapes of Siberia.

2. Research methods
Structural analysis and synthesis, mathematical modeling of mechanical and technological solutions and integral indicator of agriculture.

3. The main research results and their discussion
The low efficiency of crop cultivation is mainly due to the discrepancy between the coupling of biological and ecological cycles in various climatic zones of our country, including Siberia.

Agricultural production can be organized more efficiently by more complete and optimal use of available resources, wider involvement in technological processes of qualitatively new factors corresponding to flexible and adaptive reactions of biosystems at various levels of functioning. At the same time, the flexibility of the technology should be manifested in its ability to change the functioning program when the intended goals change, and adaptability - in the ability to obey the intended operating conditions. For efficient grain production, it is recommended [6] to actively develop an adaptive landscape farming system with a set of agrotechnologies of various levels of intensification. For this reason, the management systems used should not be too rigid, allowing you to quickly adapt not only to the "whims" of nature, but also to a sharp rise in the cost of energy and other resources, the transition to market, competitive relations. Taking into account the agro-landscape zoning, the rational structure of the use of acreage, ensuring the intensification of production, the growth of grain production is predicted [1]. Moreover, optimization of the structure of acreage in the
Siberian Federal District, on average, can provide a twofold increase in gross income [7]. And the choice of the best technologies that ensure the desired end result will be the possible management of the agricultural landscape modes, in which the compromise between the productivity of crops and the sustainability of the agroecosystem receives its final resolution. It is machine technologies that determine the level of plant productivity, efficiency and comfort of work, losses and product quality, and ultimately form the social and environmental aspects of agro-industrial production. And technical means together with the systems that provide them make up the material and technical base of technologies, the adaptation of which to natural and climatic conditions and the resource capabilities of the agricultural producer determine the level of intensity. In all cases, technologies should ensure the return on financial costs, waste disposal, and environmental cleanliness of production. At the same time, the necessary condition is the stability of the agricultural landscape and the reproduction of soil fertility [8].

Agrotechnologies, as a way of managing the productivity of agrocenoses, overwhelmingly carry out their technological impact (technological management) on the soil cover of the agricultural landscape. Moreover, any agrotechnology contains a sequence of technological operations, and the management problem itself consists in choosing the optimal number of these operations, determining their size and time of use. It is this problem that has not yet been solved even in the most modern precision farming systems [9]. And there is no universal mathematical model for practical calculations and forecasts on a wide temporal and spatial scale, and it is basically impossible to create it. The criterion of efficiency is the ratio of the result to the costs that provide it. However, to date, there is no generally recognized indicator of the economic efficiency of production. Practice shows the difficulties of solving the tasks of transferring the economy to an intensive path of development and ensuring efficiency growth. The root of failures lies not only in the underestimation at all levels of the importance of this problem, but also in the inability to manage these processes [10]. Therefore, the correct strategy is to create narrowly oriented solutions for each specific problem - modeling for a specific case [11].

Further intensification of agriculture is associated with the development of biotechnologies and an increase in the accuracy of technological operations [12]. Precision agriculture corresponds to this direction [13]. Therefore, precision farming technologies are more consistent with the really possible value of Double yield, which is an integral indicator of its assessment. To quantify the really possible yield value, we propose the following analytical expression of it:

\[ Y_{\text{ap}} = 10K_tK_{PSAR}(e^{\pi K_m} - 1)(a \pm \frac{b}{k_h}), \]

where: 10 - coefficient of yield conversion, t/ha; \(K_t\) - coefficient of heat supply; \(K_o = 1.0507\) - coefficient of development; \(K_{PSAR}\) - coefficient of photosynthetically active radiation; \(\pi = 3.14; K_m\) - coefficient of moisture; \(a, b\) - coefficients of approximation; \(k_h\) - coefficient of heterogeneity of soil cover.

The concept of agricultural technology management is known, containing four hierarchical levels for different time scales [9]. In the conditions of Siberia, these four temporary levels of control are implemented by the following technological control actions;

- the upper level is strategic management. Depending on the level of intensification of the applied agricultural technologies of SibRIACH SFSCA RAS, adaptive-mobile field crop rotations have been developed, providing maximum growth of the energy coefficient in the range of 2.72–3.09 MJ. For the arid regions of Siberia, the Research Institute of AP Khakasia has proposed a surface irrigation technology. The integrated use of the proposed technical support on the example of the construction and operation of surface irrigation systems (in comparison with existing machines in reclamation construction) provides an increase in the quality of work performed and labor productivity by 3-5 times, reduces the cost of 1 ton of hay by 3-4 times with an average yield of 5 t/ha [14]. This level of technological management contributes to the stabilization of soil fertility for a long time;
- the second hierarchical level is the management level implemented for a separate growing season. The proposed furrow-belt sowing on the basis of the Ob-4ZTU block-modular cultivator in laboratory-field and production experiments on leached chernozems allowed to establish an increase in the yield of grain crops in the amount of 20-35% compared with ordinary sowing carried out by the SGP – 3.6 seeder;

- at the third hierarchical level, real-time technological control is implemented ("on-line" mode - operational change of parameters and operating modes of the MTA). Thus, to control the heterogeneous structure of the soil cover in the agricultural landscapes of Siberia, an automatic flexible technological complex for basic tillage has been proposed, which allows improving the quality of tillage, increasing labor productivity by 15-20%, which ultimately leads to a decrease in agricultural costs of field work [15];

- the fourth is the level of technological impact based on scientific principles that take into account the physical, mechanical and technological properties of the processing object.

In general, in order to obtain the predicted yield of grain crops and the costly mechanism of its production, a method of parametric synthesis has been developed, recommended for the conditions of Siberia of three levels of intensity of agricultural technologies [16].

4. Conclusions.
In the conditions of Siberia, the presence of various soil-climatic zones, which cause a spatio-temporal change in the properties and conditions of the soil cover, requires accurate (digital) management of the resource potentials of agricultural landscapes.

To increase the efficiency of grain cultivation in the agricultural landscapes of Siberia, four technological levels of management have been proposed for various time intervals of their implementation, allowing to reduce the effects of "the vagaries of nature".

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