Assessment of phytocenoses ecological potential in south of Western Siberia based on hydrological and climatic calculations to increase agricultural production

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Abstract. The development of the agricultural sector, which provides the population with basic types of food products, is of great importance for the country’s economy. The main branches of agriculture include plant growing and animal husbandry, the effective development of which is of economic but also of significant economic and social importance. The main areas of crop production are represented by grain, vegetable farms and the cultivation of fodder crops. Of great importance for the effective cultivation of crops with sustainable crops is the farming system that is maximally adapted to local climatic and landscape conditions. In work, the ecological potential of phytocenoses was estimated, taking into account the peculiarities of the territorial distribution of heat and water resources in the south of Western Siberia. The necessity of comparing the specific ecological potential of phytocenoses with a possible technogenic load in order to ensure the stability of its functioning is shown.

1. Introduction
The territory of the south of Western Siberia is located within three natural zones: forest, forest-steppe and steppe. The forest zone, in turn, is subdivided into subzones of the taiga and birch-aspen forests. The most common type of forest in the zone is dark coniferous forests with a predominance of Siberian spruce, Siberian fir and Siberian pine (cedar). Flat areas are predominantly occupied by swamps, while forests on the watersheds are confined only to hilly, elevated places.

The presence of forest and steppe plant communities, as well as marshes, meadows and salt marshes, characterizes the forest-steppe zone adjacent to the subzone of deciduous forests of the forest zone. The main background of the forest-steppe zone is formed by meadow and herb-grass steppe.

The steppe zone is territorially the smallest in terms of the total area of the considered territory and covers the southern part and extends to the borders of the Kazakh small hills. Steppe communities represent the plant diversity of this zone with a predominance of cereal-meadow, fescue-feather grass, wormwood-fescue varieties.

Features of changes in climatic conditions from the north to south determine the main types of economic activity. Due to the low heat supply, the northern part of the territory is waterlogged and is characterized by good water supply [1] by the presence of a large number of water bodies and wetlands. The lack of moisture and the excess heat resources of the southern part determine the special
conditions for the formation of a land cover resistant to moisture deficits. The variability of heat and moisture resources forms the zonality of the ecological potential of phytocenoses.

2. Formulation of the problem
A variety of the species composition of the vegetation cover, which constitutes the dominant part of the biogenocenosis of a plot of the earth's surface, is formed depending on the physical, geographical, and climatic conditions. A set of environmental factors, the most important of which are heat energy resources and atmospheric moisture and their variability over a long period, determines the functioning and stability of natural systems [2]. Phytocenosis species are formed under similar conditions, taking into account multi-annual and seasonal variability.

These phytocenosis species belong to natural species that are in close interaction with each other and develop under the influence of heterotrophic components (animal world) and ecotope features (environmental characteristics). Consequently, in assessing the ecological technology intensity of phytocenoses, a vital role is played by the correct consideration of the characteristics of heat supply and wetting of the territory.

Agricultural activity in the south of Western Siberia is characterized by the production of cereals, industrial crops, vegetables, potatoes, as well as the development of dairy and beef cattle breeding. Thus, the development of crop production, as the basis of the agricultural sector, involves the cultivation of various crops, most of which are not related to the natural plant community of this territory. The cultivation of such cultivated plants (cereals, vegetables, fodder) and various related species (weeds) corresponds to agro phytocoenosis. Compared with the natural phytocoenosis adapted to the natural climatic, soil conditions and the conditions of the natural species composition among themselves, agro phytocoenosis can be attributed to an artificial change in biocenoses.

A change in the natural species composition can lead to an imbalance in nutrients and the formation of an unstable system. Nutrients and energy remaining in the soil under natural conditions during agro phytocoenosis are extracted together with the crop, increasing the anthropogenic load. A constant violation of the equilibrium of the nutrient medium established over a long period can lead to a sharp decrease in soil productivity and environmental sustainability of the agro-landscape. Therefore, the only condition for the normal development of agrocenoses is to provide the root-inhabited layer with additional energy through various types of land reclamation in order to improve soil fertility [3] and increase the specific ecological potential of plant communities.

3. Materials and methods
Taking into account the importance of the natural resource potential as the ability of natural systems to give the necessary products without prejudice, in [4] the value of the specific ecological potential is taken to be equal to (e₃) the annual production of the plant community (Pₐ):

$$ e₃ = Pₐ, t/km^2 \text{ year} $$

(1)

The nature of the agro phytocoenoses development, the variety of species composition, and their productivity are mainly determined by the natural-climatic and soil components of the landscape [5]. The effectiveness of the interaction of these components is an indicator of the biological productivity of the territory. It should be remembered that obtaining the maximum annual phytomass production corresponds to the maximum permissible anthropogenic load on the natural-territorial complex. In this regard, when growing crops, it is necessary to take into account conditions that do not violate the ecological balance while maintaining the ability of the landscape to self-repair.

The best conditions for the development of plant communities are achieved with optimal values of heat and moisture in the territory. The highest productivity of the vegetation cover is observed when the heat and water balance is observed. In the territory receives so much heat, which is completely spent on evaporation of the annual amount of precipitation. It is possible to use the territory with heat and energy resources and moisture, proceeding from this, as an indicator of the value of productivity.
In the works of Professor Mezentsev V.S. [6], Karnatsevich IV [7], Belonenko G.V. [8] the structure of the relationship between heat resources and moisture resources is determined by the level of moisture (in natural and artificial environments). Therefore, the indicator of heat supply and hydration of the territory for any intra-annual period is the relationship characterized by relative values of humidification (2). Total evaporation (3), the possible values of these parameters for river basins in the south of Western Siberia and adjacent territories are in the range from 0.2 to 0.6 [9]:

\[ \delta_N = \frac{L(KH)}{T_C} = \frac{KH}{Z_C} \]  \hspace{1cm} (2)

\[ \delta_Z = \frac{L(Z)}{LZ_C} = \frac{Z}{Z_C} \]  \hspace{1cm} (3)

where \( KH \) – precipitation, mm; \( Z_C \) – water equivalent of heat energy resources of the climate, mm; \( L \) – the specific heat of water evaporation equal to 2.521 MJ/(m\(^2\)∙mm); \( T_C \) – TER of climate in MJ/(m\(^2\)∙year).

The most reliable way to assess the temporal variability of the specific ecological potential of natural phytocenoses would be direct statistical processing of actual product data obtained for many specific years. However, due to the lack of such information, the variability of annual production is determined by indirect methods.

The dependence of the specific ecological potential of natural phytocenoses on temporary fluctuations in moisture and heat resources or their ratio determines the choice of types of indirect methods. In this case, it is necessary to take into account the natural and climatic features of the territory of Western Siberia that have developed over a long period, namely, the inverse dependence of the heat and moisture distribution resources. In warm years with high heat supply, there is a lack of moisture, while the limiting factor in productivity is a lack of moisture, and in wet years, plants suffer from a lack of heat. At the same time, it must be borne in mind that assessing the ecological potential of phytocenoses only by heat and moisture resources is insufficient to study their temporal variability.

4. Results and discussion

In [10], the authors succeeded in assessing the temporal variability of annual production by varying the relative or absolute characteristics of the proportionality of moisture and heat resources and describing the annual production with the moistening level of the active earth’s surface with a stable relationship. As the moisture content of the active layer, the values of relative humidity \( W / W_{LMC} \) (in fractions of the lowest moisture capacity) and absolute humidity \( W \) within a meter soil layer were taken. Figure 1 shows the communication graph obtained as a result of the studies.

A quantitative assessment of the ecological technology intensity of phytocenoses is based on data from heat and energy and water resources of meteorological stations located in the south of Western Siberia. The calculated dependence for annual production \( P_a \) (t/km\(^2\)) was obtained, taking into account the moisture content of the territory and the heat and energy resources of the climate.

Table 1 shows the values of heat and water, water characteristics and annual production for several stations in the south of Western Siberia. Analysis of the Table 1 confirms the dependence of the nature of the territorial distribution of annual production on the spatial ratio of moisture and heat resources. The values of \( P_B \) in the south of Western Siberia vary from 610 to 720 t/km\(^2\). For determining the role of moisture in the annual production distribution, a relationship was obtained depending on the amount of precipitation (Fig. 2).
It can be seen from the graph (Figure 2) that the best yield conditions are observed with precipitation of about 550 mm. Most likely, this corresponds to the optimal conditions for the ratio of heat and moisture, therefore, to the best conditions for soil moisture in similar physical and geographical conditions. The decrease in annual production with an increase in the precipitation layer is mainly associated with low heat supply.

Analysis of the graph also shows that the majority of observation points located in the southern part of Western Siberia are in conditions of moisture deficit. An increase in the annual production of agro
phytocenoses, given the existing territory with heat energy resources, can be achieved by artificial moistening of the root layer.

Figure 2. A graph of the annual production dependence of $P_a$ on the amount of atmospheric precipitation of KH in the south of Western Siberia.

5. Conclusion
Based on the results of the analysis, it is very likely that for obtaining sustainable agricultural products in the territory under consideration, it is necessary to compare the specific ecological potential of phytocenoses with a possible anthropogenic load.

The values of the specific ecological potential of phytocenoses in the south of Western Siberia depend on the hydrological and climatic conditions and are determined by the annual production of $R_v$.

The most significant annual production with existing heat and power resources in the south of Western Siberia is observed at atmospheric precipitation of 550 mm.

The obtained calculated dependences of the distribution of the ecological potential of phytocenoses make it possible to determine the impact of external influences on the ecosystem, which, in turn, will ensure the stability of its functioning.

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