Identification of the agroecological potential of agricultural land use

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Abstract. At present, the sustainable development of rural areas is one of the main goals of modern state agrarian policy. The system of modern agricultural land use should be formed under the influence of economic, social, legal, environmental and natural conditions of the territory. The authors of modern scientific publications on the sustainability of agricultural land use often consider the concept of sustainability from an agroecological point of view, as maintaining fertility and preventing negative processes. Agroecological capacity is the most important factor affecting agricultural land use efficiency. The paper considers the role of agroecological potential in the system of sustainable agricultural land use. A survey of domestic sources on the importance of agroecological and bioclimatic potential in enhancing the sustainability of agricultural land use was conducted. The concept of agroecological potential of agricultural land use was clarified. The object of the study is the agricultural land use in Volokolamsk district of Moscow region. A comprehensive analysis of financial results of agricultural enterprises and organizations in Moscow region was carried out, which showed low profitability of agricultural land use. The methodology and calculation of agroecological potential of agricultural land use in Volokolamsk district of Moscow region were considered. The measures to increase the possibility of using the generalized assessment of bioclimatic and agroecological resources of Volokolamsk district of Moscow region were proposed and the efficiency assessment on main crops over the past 15 years and comparison with the values of bioclimatic potential of agroecological potential for agricultural land management purposes was performed. The modern principles of sustainable agricultural land use require the placement and specialization of agricultural production in accordance with the agroecological conditions of the territories.

1. Introduction
At present, the sustainable development of rural areas is one of the main goals of modern state agrarian policy. The concept of sustainable land management is understood by many of them as a form of land management that may ensure environmental principles of production while maintaining the required level of economic profitability.

Numerous studies of sustainable agriculture and rural development showed that sustainable agricultural land use [1–4]:
- creates and controls natural biological cycles;
- minimizes harmful effects on health, nature, water quality and the environment;
- protects and restores soil fertility and natural resources;
- optimizes the use of non-renewable resources;
- improves the efficiency of all types of resources in enterprises of all forms of ownership;
- increases the competitiveness and efficiency of agriculture;
- improves the quality of life and ensures a stable income for the rural population.

The system of modern agricultural land use should be formed under the influence of economic, social, legal, environmental and natural conditions of the territory. The authors of modern scientific publications on the sustainability of agricultural land use often consider the concept of sustainability from an agroecological point of view, as maintaining fertility and preventing negative processes. The very concept of sustainable land management is interpreted by many of them as a form of land management that may ensure environmental principles of production while maintaining the required level of economic profitability.

A.A. Varlamov believes that three main aspects should be taken into account in assessing the sustainability of agricultural land use: spatial, economic and environmental [5].

O.A. Tkacheva and E.G. Meshchaninova propose an environmental and economic score that takes into account environmental sustainability, anthropogenic load, arable land afforestation, land use intensity and other indicators as a criterion for assessing the sustainability of agricultural land use [6].

N.V. Polshakova understands the stability of land use as the consistency of soil fertility on a considered land. The author proposes a set of measures for the transition of agro-industrial enterprises to sustainable land use [7].

Sustainable agricultural land use is reflected, in our view, in the sustainability of the landscape-ecological system, the formation of which is determined by the requirement for the greatest reliability. The sustainable agricultural land use in accordance with environmental conditions implies the maximum economic effect on agricultural lands taking into account the ecological balance (land protection), preserving and improving the landscape.

In the process of agricultural land use, it is possible to obtain an ecological effect, which is characterized by the creation of conditions for the conservation and improvement of land resources and other elements of the natural environment as a result of the management of objects, the reproduction of soil fertility, the prevention and cessation of land degradation, the deterioration of their cultural and land reclamation status, the development of other negative phenomena, as well as the increase in the level of environmentally sustainable development of rural areas.

The efficiency of agricultural land use cannot be improved without an information base on the fertility of agricultural land. At the same time, the need to obtain up-to-date, reliable and complete information increases in the conditions of obsolescence of data from soil surveys conducted back in the 60-80s of the past century.

Soil fertility and yield, respectively, are influenced by factors such as heat and moisture. After all, soil fertility should be considered as a complex value, depending not only on the mechanical composition, physicochemical and water-physical properties of the soil material, but also on climatic factors [8].

Natural potential, including the full range of natural resources, natural and climatic conditions, has always played a special role in society, thus affecting the economic development in various countries. In our country, at the beginning of the 20th century, two different approaches to determining the most important factors of agricultural land use were distinguished – agroclimatic and agroecological. In the first case, within the agroclimatic approach, soil-climatic conditions were usually considered as the main factor determining the possibilities of cultivation and placement of various crops. With an agroecological approach, the cultivated plant and its specific requirements for environmental conditions are put forward as central, and all the rest – soil, climate, weather – as secondary.

In our view, agroclimatic and agroecological potentials are the most important factors affecting agricultural land use efficiency. Agroclimatic potential, as well as soil bonitet, primarily depends on the adaptive and medium-improving capabilities of a particular crop (variety) or a corresponding set of crops (varieties). Thus, the greater or lesser total yield of agricultural products from a given territory and the efficiency of production will be determined by the agrobiological properties of cultivated
species and varieties of plants. Such properties include the type of soil, the duration of the growing season, potential yields, the level of crop species and others.

Agroecological potential was developed at the Soil Institute named after V.V. Dokuchaev under the leadership of I.I. Karmanov and characterizes the influence of climatic conditions on the yield of grain crops. Agroecological potential is part of the soil-ecological index. Agroecological potential (AP) characterizes the influence of climatic conditions on crop yields and is calculated by the following formula:

$$ AP = \frac{\sum t > 10^\circ (HF - P)}{CC + 100}, (1) $$

where $\sum t > 10^\circ$ – sum of temperatures above 10 °C is taken from climatic (agroclimatic) directories (it is possible to calculate its distribution over the slope); HF – humidity factor (ratio of precipitation D (mm) to evaporability E); HF values more than 1.1 are accepted equal to 1.1; P – correction to HF, at HF>0.76, P=0.20-0.6 (1.1–HF); HF=0.76-0.36, P=0; HF=0.35–0.30, P=0.35 – HF; HF<0.30, P=0.05; CC – coefficient of continentality (for the studied territory equals 187).

The agroecological potential of the territory, as well as the bioclimatic, characterizes, first of all, the potential productivity and environmental sustainability of certain species and varieties of plants.

According to scientists led by Professor S.N. Volkov together with T.P. Fedoseeva, A.A. Bubashkina, T.A. Emelyanova, S.I. Nosov, V.P. Rodionov, V.N. Semochkin, who developed a methodology for integrated agroecological assessment of land, the agroecological potential of land depends on a combination of agroecological regimes and factors and is assessed by indicators of the productivity of agrocenoses, the ability of land to produce a wider range of products [9].

Taking into account the developments of V.D. Skalaban and P.F. Loyko, the agroecological potential of land ($I$) can be defined as the potential productive force (productivity) of a unit area (ha) expressed by energy (feed) units. Agroecological land resources ($N$) can be defined as the total productivity of the entire agricultural land area of the region [10]:

$$ N = \sum_{i=1}^{n} I_i S_i, (2) $$

where $i = 1, 2, 3, ...n$ – number of the land plot; $n$ – number of land plots; $I_i$ – agroecological potential, potential productivity of the unit area (ha) of the $i$ land plot, expressed in comparable energy (feed) units; $S_i$ – area of the $i$ land plot; $N$ – total productivity of $n$ estimated land plots, expressed in comparable energy (feed) units. Agriculture in the process of agricultural land use is the transformation of the radiant energy of the Sun into the energy of chemical bonds of organic compounds. Therefore, the solar radiation $R$ coming to the Earth’s surface is the most common, absolute characteristic of the agroecological potential, and the conditions for cultivating the crop, their correspondence to its biological characteristics determine the efficiency of using the potential of this crop. Theoretically, the possible limit for the use of $R$ by a green plant cell is $\alpha = 15\% \ R$, or 30% of its photosynthetically active radiation (PAR).

Modern principles of sustainable agricultural land use require the placement and specialization of agricultural production in accordance with the agroecological conditions of the territories. The criterion for the effectiveness of agricultural land use should not be short-term economic profitability, but the fullest use of the agroecological potential [11].

2. Materials and methods
The object of the study is agricultural land use in Moscow region, where agricultural production does not always take into account the correspondence of the biological characteristics of crops to soil and climatic conditions.

A comprehensive analysis of financial results of agricultural enterprises and organizations in
Moscow region showed low profitability of agricultural land use. The level of profitability of agricultural production in Volokolamsk district of Moscow region is minus 57.9%, while in the area of agricultural land they occupy more than 50% (Table 1).

**Table 1. Financial results of agricultural organizations of Volokolamsk district of Moscow region**

| Financial indicator                        | Indicator values |
|--------------------------------------------|------------------|
| Number of enterprises                      | 9                |
| Number of profitable enterprises           | 5                |
| Profit before tax, thousand rubles         | 13628            |
| Number of loss-making farms                | 4                |
| Share of unprofitable farms, %             | 44.4             |
| Loss before tax, thousand rubles           | 240934           |
| Profit before tax, thousand rubles         | -227306          |
| Profitability level for all activities, %  | -57.9            |

On the territory of Volokolamsk district of Moscow region, the $R$ value is about 400 kJ/sm²-year, which indicates large energy reserves for increasing agricultural productivity of land.

The agroecological potential of land for a particular crop is characterized by its productivity $M_{c/ha}$, which is determined by the following formula:

$$M = \sum_{t=ts}^{th} \frac{R(t) \cdot \alpha(t)}{m(t)}, (3)$$

where $t$ – calendar date, days; $ts$ – sowing date; $th$ – harvesting date; $R(t)$ – daily radiation, kJ/ha-day; $\alpha(t)$ – share of solar radiation, m(t) – amount of energy in product unit, kJ/c.

Climate resources are typically assessed with bioclimatic potential $B_k$:

$$B_k = K_t \cdot K_v \cdot 100, (4)$$

$$K_t = \frac{\sum T > 10^\circ C}{1900^\circ C}, K_v = 1 - (1 - P/E)^2$$

$$B_k = \frac{\sum T > 10^\circ C}{1900^\circ C} \cdot [1 - (1 - P/E)^2] \cdot 100$$

where $B_k$ – bioclimatic potential; $K_v$ – coefficient characterizing the solar energy resource; $K_t$ – coefficient characterizing atmospheric moistening; $\Sigma T > 10^\circ C$ – annual sum of physiologically active average daily temperatures exceeding $10^\circ C, 1900^\circ C$ – average for the agricultural territory of Russia $\Sigma T > 10^\circ C$; $P$ – precipitation per year, mm; $E$ – evaporability per year, mm.

The equations show that with sufficient atmospheric humidification ($P=E$) and the average for the agricultural territory of Russia, the intake of solar energy ($\Sigma T > 10^\circ C = 1900^\circ C$), the bioclimatic potential $B_k=100$ points.

Bioclimatic resources become energy resources as a result of crop cultivation. Let us consider the efficiency of converting bioclimatic resources into energy (feed), which is determined by three main groups of factors:

1) use of high-yielding crops and their varieties in agriculture with an active photosynthetic apparatus that utilizes high percentage of PAR (physiologically active radiation of the Sun), in which the share of the final marketable product of the total phytomass is high and the mass of by-products (straw, herbage, etc.) is insignificant;
2) use of late-ripe crops and their varieties in agriculture, most fully using the solar energy resource from the beginning of the warm period to its end;

3) maximum compliance with agricultural equipment recommended for zoned crops and their varieties, maximum approximation of agricultural equipment to the requirements of SCP (state crop plots).

These groups of factors determine the use of bioclimatic resources and the effectiveness of agriculture in individual farms and in the area as a whole. The number of feed units per 1 B_k point is a measure, an assessment of the effectiveness of agriculture (Table 2) [10].

**Table 2. Assessment of agricultural efficiency by the number of energy (feed) units per 1 point of bioclimatic potential B_k**

| Index  | Soil management efficiency | B_k score c/ha |
|--------|----------------------------|----------------|
| 1.1    | Low                        | 0.13           |
| 1.2    | Low                        | 0.13–0.18      |
| 1.3    | Low                        | 0.18–0.23      |
| 2.1    | Low                        | 0.23–0.30      |
| 2.2    | Medium                     | 0.30–0.38      |
| 2.3    | High                       | 0.38–0.46      |
| 3.1    | High                       | 0.46–0.53      |
| 3.2    | High                       | 0.53–0.61      |
| 3.3    | High                       | 0.61 and more  |

3. Results
A generalized assessment and efficiency analysis of bioclimatic and agroecological resources of Volokolamsk district of Moscow region was carried out on the main crops over the past 15 years and compared with the values of bioclimatic potential (B_k). Table 3 shows the calculations obtained to determine the extent to which the bioclimatic resources of the area are used.

The results show that the most complete use of bioclimatic resources of the region is achieved in growing vegetables and fodder root crops. The energy value of the B_k score is estimated as increased and high.

**Table 3. Assessment of the effectiveness of the bioclimatic potential in Volokolamsk region**

| Yield of cereal crops, c/ha (conversion factor 1.2) | 2008 | 2009 | 2010 | 2011 | 2012 | 2013 | 2014 | 2015 | 2016 | 2017 | 2018 | 2019 | n   | average c/ha | c/ha*B score |
|---------------------------------------------------|------|------|------|------|------|------|------|------|------|------|------|------|-----|--------------|--------------|
| Steblevo                                          | 20.0 | 27.5 | 23.1 | 25.7 | 22.1 | 9.6  | 13.8 | 7.1  | 16.8 | 14.0 |      | 10   | 18.0 | 21.6 | 0.21 | 13            |
| Named after XXII Congress of the CPSU             | 19.9 | 24.1 | 13.7 | 21.0 | 13.3 | 9.0  | 9.5  |      |      |      |      |      | 7    | 15.8 | 18.9 | 0.18 | 13            |
| Bolychevo                                         | 20.1 | 23.2 | 15.9 | 19.8 | 19.8 | 10.2 | 13.7 | 19.2 | 19.5 | 12.0 | 14.3 | 12.4 | 6.4  | 2.4  | 14 | 14.9 | 17.9 | 0.17 | 12            |
| Teryaevsky                                        | 23.2 | 26.2 | 22.3 | 20.2 | 29.0 | 14.6 | 23.4 | 20.0 | 23.2 | 13.8 | 22.0 | 22.4 | 9.9  | 3.6  | 14 | 19.6 | 23.5 | 0.22 | 13            |
| Chismensky                                        | 26.5 | 27.0 | 15.4 | 14.2 | 14.6 | 6.8  | 13.5 | 22.5 | 25.9 | 16.0 | 14.5 | 8.4  | 6.7  | 2.4  | 14 | 15.3 | 18.4 | 0.18 | 13            |
| Sudnikovsky                                      | 23.9 | 29.0 | 18.2 | 25.0 | 30.2 | 13.7 | 18.9 | 16.9 | 16.3 | 14.6 | 15.0 | 15.2 | 9.9  | 4.6  | 14 | 18.0 | 21.5 | 0.21 | 13            |
| Yaropoletsy                                      | 23.1 | 28.0 | 19.6 | 20.7 | 22.5 | 13.0 | 18.6 | 21.3 | 22.4 | 16.2 | 23.2 | 22.9 | 17.0 | 9.0  | 14 | 19.8 | 23.8 | 0.23 | av1           |
| Karmanovsky                                      | 25.2 | 28.8 | 14.1 | 18.6 | 18.7 | 9.3  | 12.1 | 20.5 | 17.9 | 6.7  | 11.5 | 7.1  | 1.7  | 0.6  | 14 | 13.8 | 16.5 | 0.16 | 12            |
| Shestakovsky                                     | 23.0 | 28.0 | 19.6 | 20.7 | 22.5 | 13.0 | 18.6 | 21.3 | 22.4 | 16.2 | 23.2 | 22.9 | 17.0 | 9.0  | 14 | 19.8 | 23.8 | 0.23 | av1           |
| Panfilovsky                                      | 20.1 | 28.0 | 18.0 | 21.4 | 14.9 | 7.0  | 15.2 | 21.2 | 16.2 | 8.7  | 10.2 | 9.6  | 9.7  | 1.0  | 14 | 14.4 | 17.3 | 0.16 | 12            |
| Lvosky                                           | 24.4 | 30.9 | 24.2 | 30.4 | 23.2 | 14.3 | 15.1 | 15.9 | 17.8 | 14.2 | 18.0 | 5.0  | 12   | 19.5 | 23.3 | 0.22 | 13            |
| Volokolamsk                                      | 27.0 | 32.0 | 25.9 | 24.0 | 22.0 | 14.8 | 17.1 | 18.5 | 19.2 | 13.0 | 16.2 | 9.6  | 4.0  | 1.9  | 14 | 17.5 | 21.0 | 0.20 | 13            |
| Holmogorka                                       | 28.0 | 36.6 | 27.8 | 30.9 | 26.8 | 16.0 | 24.5 | 20.8 | 27.6 | 19.1 | 15.0 | 18.3 | 6.3  | 1.8  | 14 | 21.4 | 25.7 | 0.24 | av1           |
| Put Ilyichinos                                  | 32.7 | 33.6 | 23.5 | 33.1 | 30.5 | 13.6 | 22.5 | 24.0 | 20.8 | 15.5 | 20.7 | 20.6 | 13.5 | 6.4  | 14 | 22.2 | 26.7 | 0.25 | av1           |
| Udamak                                          | 23.6 | 25.2 | 18.4 | 14.5 | 15.2 | 7.1  | 4.9  |      |      |      |      |      |      | 7    | 15.6 | 18.7 | 0.18 | 13            |
| Avangard                                        | 27.6 | 35.5 | 30.5 | 28.4 | 32.2 | 18.5 | 32.8 | 34.6 | 38.0 | 24.7 | 24.0 | 18.2 | 8.8  | 2.3  | 14 | 25.4 | 30.5 | 0.29 | av1           |

*Av1 – above average, *Av2 – average, *Av3 – below average
4. Conclusion

The results obtained from the application of natural-agricultural characteristics of land, in particular agroecological and bioclimatic potential, make it possible to draw reasoned conclusions on improving the agricultural land use at various administrative-territorial levels.

To summarize the above, at present the most important factors in the application of agro-ecological and agro-climatic potential of the agricultural land use are the improvement of effective fertility through the use of mineral fertilizers and technology, as well as the strictly differentiated use of natural resources.

Besides, we believe that the following is required:
- to improve phytosanitary well-being of agroecosystems and agrolandscapes by wide use of crops and varieties resistant to harmful types;
- to increase the scientific intensity of intensification processes due to selection, use of the latest crop cultivation technologies, agroecological macro-, meso- and microzoning of the territory, design of adaptive agrobiogeocenoses and agrolandscapes;
- to cultivate crops (varieties) and apply agronomic methods (technologies), to make them comply as close as possible to soil, climatic and ecological features of the territory.

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