Features of a systematic environmental assessment of the agricultural landscapes in the chestnut soils arid steppe

A M Belyakov\textsuperscript{ORCID 0000-0002-9541-8383}, M V Nazarova\textsuperscript{ORCID 0000-0002-7933-3152}

Federal Research Center for Agroecology, Complex Melioration and Protective Afforestation of the Russian Academy of Sciences, Volgograd, Russia

E-mail: mn1967@list.ru

Abstract. Most of the modern agricultural landscapes (agrolandscapes) are significantly deformed in a varying degree. The relevance of systemic assessments of agricultural landscapes lies in prompt and objective identification of their ecological state and deviations, as well as timely development of measures for restoration and preservation of ecosystems. The methodological basis of the research is presented in the works by A.N. Kashtanov, A.A. Zhuchenko, V.A. Nikolaev, V.I. Kryushin, A.G. Isachenko, M.I. Lopyrev, N.P. Masyutenko and other scientists. The conducted research has allowed revealing a significant impact of agricultural technologies and farming systems (up to 72–78%) on the agrolandscape of the arid zone of chestnut soils of the Volgograd region. The combination of these factors can lead the agricultural objects under study to a high degree of ecological balance or, conversely, to degradation. The authors have developed the system of criteria for direct, indirect and integrated assessment of the state of agricultural landscapes of steppe and dry-steppe zones of the Volgograd region. These criteria are estimated in points from 1 to 5: 5 points (absolutely balanced), 4 points (balanced), 3 points (medium balanced), 2 points (poorly balanced), 1 point or less (unbalanced). This assessment system has been tested on real objects. When calculating the average point, object "C" had 2.3 points (poorly balanced); object "I" – 2.9 points (medium balanced); and object "U" – 3.6 points (relatively balanced). The developed system of direct, indirect and integrated assessment of the state of agricultural landscapes for the conditions of insufficient humidity allows for objective evaluation of agricultural objects in terms of their ecological balance. The system can be used as the basis for regulation of anthropogenic load on the agricultural sphere as well as for timely adoption of organizational and technological measures aimed at restoration of ecological balance in the conditions of insufficient humidity peculiar of the southern regions of the Russian Federation.

1. Introduction
At a certain stage of scientific and technological progress and production development, larger territories, such as agrolandscapes and agroforestry landscapes, used in production activities, became the objects of agrarian science. They represent a complex of interrelated natural and anthropogenic connections and manifest more clearly the causal links of degradation and restoration processes.

Most of the modern agricultural landscapes are significantly deformed in a varying degree as compared to their original natural state due to the active economic use. Soil, relief, forest cover, photosynthesizing ability have undergone greater changes, which significantly reduce the production and ecological potential of the lands [1].

The theoretical basis for the studies of environmental sustainability and agrolandscapes functioning was laid by outstanding scientists V.V. Dokuchaev, V.I. Vernasky, V.R. Williams and is presented in
a number of Russian and foreign works [2-7]. We should also note the great contribution of Russian scientists A.G. Isachenko, M.I. Lopyreva, N.P. Masyutenko to the development of the theory and methodology of research on the formation of ecologically balanced agricultural landscapes, the system of rational land use [8-11].

The methodology and the need for a systemic approach in the study of rational nature management with scientific substantiation of the formation of ecologically balanced agro-ecosystems and agrolandscapes is presented in the works by A.N. Kashtanov, A.A. Zhuchenko, V.A. Nikolaev, V.I. Kiryushin and other scientists [12-14, 1, 15-18].

The research aim is to study the processes occurring in modern agricultural landscapes and to develop an assessment system of ecologically balanced agroforestry landscapes in the dry-steppe zone of chestnut soils on the basis of the conception of effective use of natural resources and improvement of the methodology of scientific knowledge about landscapes.

The relevance, necessity and demand for systemic assessments of agricultural landscapes is very high. Their application will make it possible to quickly and objectively identify the state of the object, the causal relations of changes and to develop measures for preservation and restoration of ecosystems.

2. Models and Methods

The research methods include the method of obtaining information from stationary objects, the method of studying space images, the methods developed by the Federal Scientific Center of Agroecology, Complex Reclamation and Protective Afforestation (RAS), All-Russian Scientific Research Institute of Agriculture and Soil Protection from Erosion, Rosinformagrotech Federal Research Institute, the Methodology of the State Variety Testing of Agricultural Crops (1985) and the developments by V.I. Kiryushin, A.G. Isachenko, M.I. Lopyrev, N.P. Masyutenko, A.L. Ivanov [1, 8, 19, 10, 11, 20-24].

3. Results and Discussion

The studies have shown that agro-technology, agro-technological methods, territorial organization, forest protection have the most significant impact on the way of using agricultural land, arable land in particular. These factors ultimately determine the ecological balance and sustainability of agricultural landscapes.

Agricultural technologies include the type of basic soil cultivation, zonal elements of agricultural technology of cultivated crops (sowing time, seeding rates, seed placement depth), fertilization system, volume and method of protective complex application, care measures, intensity and nature of technical means use, a way of harvesting and products storage.

We have revealed a significant impact of agricultural technologies and farming systems (up to 72-78%) on the agrolandscapes of the arid zone of chestnut soils of the Volgograd region, including sowing structure, types of crop rotation, methods and types of basic tillage, intensity and nature of the use of technical means, the method of harvesting and storage of products, the level of nutrients subtraction and the fertilizer application system, the volume and method of application of the protective complex of phytocenoses, the method of management and afforestation of territories, manifestations of water and wind erosion, the applied measures of anti-erosion soil protection. The combination of these factors can lead the object of research to a high degree of ecological balance or, conversely, to its degradation.

We have therefore developed a system of criteria for direct (nine indicators), indirect (five indicators) and integrated (five indicators) assessment of the state of agrolandscapes of the steppe and dry-steppe zones of the Volgograd region. They are estimated in points from 1 to 5.

The system of direct criteria for the impact on agrolandscapes should include:

• productivity of agricultural crops (in a land plot, field, crop rotation, land use area, agrolandscape, landscape, district, region);

• characteristics of territorial organization (area and density of forest cover, size and configuration of fields, organization of land use depending on relief);
manifestations of water and wind erosion (dissection of relief, slopes, mechanical composition of soil, type of basic tillage);
• degree of plowing and proportion between agricultural categories;
• sowing structure (share of perennial grasses, legumes, annual crops, type of crop rotation, presence of ameliorants in crops);
• soil fertility (% of humus in soil, soil supply with macronutrients and the volume of return of nutrients);
• number of treatments during the growing season and the amount of chemicals used;
• changes in the basic parameters of soil physics (bulk density, water permeability, soil moisture capacity);
• reserves of productive moisture in soil in early spring and before harvesting.

As a result, the average indicators of direct criteria for the impact on the agrolandscape have been calculated (in points, % and relative units).

The system of indirect criteria for the impact on agrolandscapes should include:
• area allocated for roads;
• availability of communication means (communication lines, power transmission lines, pipelines) and occupied area;
• landfills, quarries (their number, occupied area and degree of impact);
• proximity of cities, settlements, industrial facilities, etc. and degree of their impact;
• soil and climatic vulnerability of the territory.

As a result, the average indicators of indirect criteria for the impact on the agrolandscape have been calculated (in points, % and relative units).

We have also developed a system of integrated indicators that express the state of the agrolandscape in relative and absolute terms. We offer the following types of integrated criteria for assessment:

1. Summarized direct criterion. It is determined by a simple summing of points obtained for all individual criteria. This type can range from 10 to 50 points.
2. Relative direct criterion. It is calculated by dividing the total amount of points by the number of direct indicators and is determined in relative values or points from 1 to 5.
3. General direct criterion. This criterion is determined as the sum of the average values of direct and indirect indicators for assessing the state of the agrolandscape (1-25 points):

\[ K_{gen} = \frac{K_{dir} + K_{indir}}{N_i}, \]

where \( K_{dir} \) – average value of direct indicators for assessing the state of the agrolandscape; \( K_{indir} \) – average value of indirect indicators for assessing the state of the agrolandscape; \( N_i \) – number of indicators.

Let us note that the impact of direct and indirect criteria on agrolandscapes should be taken into account in calculations in the ratio 4:1.

4. Criterion relative in terms of production levels. It is calculated through the ratio of crop capacity to soil fertility (from 0.2 to 5 units):

\[ K_{rel.} = \frac{K_{cap}}{K_{fer}}, \]

where \( K_{cap} \) – criterion of crop capacity; \( K_{fer} \) – criterion of soil fertility.

5. General total criterion. It is determined as the product of average values of direct and indirect indicators for assessing the agrolandscape by to the formula:

\[ K_{gen} = \frac{K_{dir} K_{indir}}{100} \]
We suggest assessing agro-landscapes in points on the following balance scale: 5 points (absolutely balanced), 4 points (balanced), 3 points (medium balanced), 2 points (poorly balanced), 1 point or less (unbalanced).

This methodology has been tested on real objects, including such land use facilities as AO Ust-Medveditskoe (object "U"), private farm of V.V. Isaev located in the Serafimovichsky district (object "I") and the Cherensky agricultural industrial complex located in the Kletsky district (object "C"). All of these sites are located in the dry-steppe zone of chestnut soils.

According to assessment results, 5 criteria for object "C" are unbalanced, 3 criteria are partially balanced, and only 2 criteria are balanced. As for object "I", 4 indicators are unbalanced, 4 are partially balanced, and 2 are balanced. The assessments for object "U" show that 5 indicators are unbalanced, and 5 are balanced.

When calculating the average point, object "C" had 2.3 points, or poor balance, object "I" – 2.9 points, or medium balance, and object "U" – 3.6 points, or balanced agro-landscape. Thus, the studied agrolandscapes have different ecological balance.

4. Conclusion

The conducted research has allowed determining the directions of agricultural landscapes greening, developing the system of impact of agro-technological factors, such as the structure of sowing, crop rotation, methods of basic tillage, the level of nutrients subtraction, the rates of fertilization, the protective complex of phytocenoses, the method of territory organization, forest cover and anti-erosion protection for ensuring ecological balance of the agricultural landscape and farming systems. These factors can lead the object of research to a high degree of ecological balance or, conversely, to its degradation.

The developed system of direct, indirect and integrated assessment of the state of agricultural landscapes for the conditions of insufficient humidity allows for objective evaluation of agricultural objects in terms of their ecological balance. The system can be used as the basis for regulation of anthropogenic load on the agricultural sphere as well as for timely adoption of organizational and technological measures aimed at restoration of ecological balance in the conditions of insufficient humidity peculiar of the southern regions of the Russian Federation.

References

[1] Kiryushin V I 2000 Greening the Agriculture and Technological Policy (Moscow: Publishing house of the Moscow Agricultural Academy) p 473
[2] Armand D L 1975 Landscape Science: (Fundamentals of Theory and Logical-Mathematical Methods) (Moscow: Mysl) p 288
[3] Isachenko A G 1991 Landscape Science and Physical-Geographical Zoning (Moscow: Higher school) p 366
[4] Kiryushin V I 2011 Theory of Adaptive Landscape Agriculture and Design of Agrolandscapes (Moscow: Kolos) 443 p
[5] Odum E P 1971 Ecology (Holt London) 152 p
[6] Malezieux E 2012 Designing Cropping Systems from Nature Agronomy for Sustainable Development 32 pp 15-29
[7] Dore T, Makowski E, Munier-Jolain, Tchamitchian M and Tittonell P 2011 Facing up to the Paradigm of Ecological Intensification in Agronomy: Revisiting Methods, Concepts and Knowledge Eur J. Agron doi: 10.1016/j.eja. 2011.02.006
[8] Isachenko A G 1980 Methods of Applied Landscape Research (Leningrad: Science) p 224
[9] Lopyrev M I, Nedikova E V and Khartonov A A 2015 Agrolandscape as a Factor of Sustainable Land Use and Land Management Bulletin of the Voronezh Agrarian University 4-2 (47) pp 179-183
[10] Masyutenko N P, Chuyan N A, Bakhirev G I, Kuznetsov A V, Glazunov G P, Dubovik E V, Pankova T I 2011 The System of Indicators for Assessing the Ecological Capacity of
Agricultural Landscapes for the Formation of Environmentally Sustainable Agricultural Landscapes (Kursk: RAAS) 42 p

[11] Masyutenko N P, Chuyan N A Bahirev G I, Kuzneckov A V, Breskina G M, Dubovik E V, Masjutenko M N, Pankova T I, Kaluzhskih A G 2013 A System for Assessing the Sustainability of Agricultural Landscapes for the Formation of Ecologically Balanced Agricultural Landscapes (Kursk: RAAS) 50 p

[12] Kashtanov A N, Lisetskiy F N and Schwebs G I 1994 Fundamentals of Landscape-Ecological Agriculture (Moscow: Kolos) p 127

[13] Zhuchenko A A 1994 Strategy of Adaptive Intensification of Agriculture (Conception) (Pushchino: RAS) p 148

[14] Nikolaev V A 1979 Problems of Regional Landscape Science (Moscow: Publishing House of Moscow University) p 160

[15] Sukhoy P A et al 2015 Environmental Assessment of Aerolandscape Systems at the Regional Level Bulletin of the Tyumen State University. Ecology and nature management vol 1 3(3) pp 6-16

[16] Kosolapov V M, Trofimov I A, Trofimova L S and Yakovleva E P 2010 Agricultural Landscapes of the Volga Region. Zoning and Management (Moscow-Kirov: Press House VYATKA) p 335

[17] Avessalomova I A 1992 Environmental Assessment of Landscapes (Moscow: Moscow State University) p 87

[18] Aydarov I P 2007 Organization of Agricultural Landscapes in Russia (Moscow: MGUP) p 159

[19] Lopyrev M I 2012 Organization of Agricultural Landscapes for Sustainable Agriculture (Voronezh: Voronezh GAU) p 108

[20] Kiryushin V I, Ivanov A L (eds.) 2005 Agroecological Assessment of Lands, Design of Adaptive Landscape Systems of Farming and Agricultural Technologies (Moscow: Rosinfor-Magrotech) p 794

[21] Pavlovsky E S 1992 Conception of Modern Agroforestry (Volgograd: VNIALMI) p 39

[22] Barabanov A T et al. 1993 Agroforestry in Soil-Protective Agriculture (Volgograd: VNIALMI) 156 p

[23] Gostev A V, Pykhtin I G, Plotnikov L B and Pykhtin A I 2017 A System for Assessing the Ecological Balance of the Agricultural Landscape and the Degree of Compliance with the Farming System. Agriculture 8 pp 3-6

[24] Methodology of State Variety Testing of Agricultural Crops Issue 1 1985 (Moscow) p 269