ANNOTATION
of the dissertation work by Marzhan Balkozha
on the topic « The condition of kastanozem soils in the southern part of Kostanay region and the approaches to enhance assessment of their fertility»
submitted for the degree of Doctor of Philosophy (PhD) in the specialty 6D080800 – «Soil Science and Agrochemistry»

Relevance of the research topic. A comprehensive assessment of the current state of kastanozem soils in the dry steppe zone of the Kostanay region is necessary, as these soils are subject to intense climatic and anthropogenic influences. Increasing climatic aridity, frequent droughts, and unstable moisture conditions have intensified degradation processes, resulting in reduced fertility, deterioration of soil structure, and declining productivity.

The region's kastanozem soils are a key resource for grain farming in Kazakhstan. However, they have long been exposed to intensive agricultural pressure, leading to changes in their natural properties and the formation of post-agrogenic landscapes. Currently, a significant proportion of these territories is characterized by an unstable condition in which degradation and partial restoration processes occur simultaneously, depending on climatic conditions and vegetation cover.

Particular importance is attached to identifying patterns of interaction between soil and biotic components of agroecosystems, including vegetation as an important bioindicator of land health. The use of modern remote sensing methods, in particular the NDVI vegetation index, in combination with long-term meteorological data, allows for a more accurate assessment of productivity dynamics and the degree of land degradation.

Despite existing studies, the complex relationships between climatic factors, vegetation status, and degradation processes in kastanozem soils of the southern Kostanay region remain insufficiently understood. The lack of integrated approaches to assessing their condition limits the ability to predict productivity and develop effective measures for sustainable land use.

In this regard, the development of a Land Degradation Index (LDI) model based on a comprehensive analysis of climatic conditions, vegetation cover, NDVI data, and soil characteristics is highly relevant. The results obtained will improve the accuracy of soil condition diagnostics, identify key drivers of soil degradation, and provide a scientific basis for monitoring and forecasting changes in agricultural landscapes under a changing climate.

Research Tasks. To assess the current state of kastanozem soils in the southern Kostanay region, taking into account the influence of climatic factors and vegetation cover; to identify patterns and drivers of their degradation; to construct a degradation process model; and to develop an integrated degradation index based on this model.

Research Objectives:

- analyze long-term data on climatic conditions in the area of kastanozem soil distribution in the dry steppe zone of the Kostanay region;

- study the current state of kastanozem soils and identify the causes of degradation;

- determine the species composition and bioindication indicators of vegetation in the southern Kostanay region;

- assess and predict plant yields on kastanozem soils in the dry steppe zone of the Kostanay region;

- assess the vegetation condition of experimental fields based on the NDVI vegetation index and determine the relationship with long-term meteorological indicators and the productivity of terrestrial plants;

- develop a model of the integrated degradation index (LDI) for kastanozem soils in the southern part of the Kostanay region.

Research Methods. The study employed field-based soil morphological, geobotanical, biometric, laboratory, comparative analytical, statistical, geoinformation (GIS), and remote sensing methods. The morphogenetic characteristics of kastanozem soils were investigated, and the chemical composition of soil samples was determined using the methods of I.V. Tyurin, Kjeldahl, B.P. Machigin, N.I. Savvinov, and K.K. Gedroits. The species composition of the vegetation cover, plant height, and aboveground phytomass productivity were assessed. Long-term climatic data were analyzed using comparative analytical and statistical methods. To evaluate the condition of the vegetation cover and the degree of land degradation, Sentinel-2 satellite imagery and GIS technologies were employed, and the Normalized Difference Vegetation Index (NDVI) and the Land Degradation Index (LDI) were calculated.

Main provisions submitted for defense (proven scientific hypotheses and other conclusions that constitute new knowledge):

1. An analysis of the climatic conditions of the Kostanay region was conducted to assess the condition of kastanozem soils in the dry steppe zone.

2. It was established that the current condition of kastanozem soils in the southern part of the Kostanay region is influenced by climatic factors, vegetation cover, and anthropogenic impacts, which determine their spatiotemporal variability and the degree of degradation associated with long-term climate dynamics.

3. The research covered species composition and bioindication indicators of vegetation, reflecting the degree of soil cover transformation used as indicators of ecosystem health.

4. The average plant yield on kastanozem soils over the study period was determined, taking into account soil-climatic conditions and vegetation cover in the dry steppe zone of the Kostanay region.

5. Significant correlations were established between the NDVI, meteorological parameters, and vegetation productivity, demonstrating their potential for assessing land condition.

6. A model of the integrated degradation index (LDI) has been developed, providing a comprehensive quantitative assessment of the degree of degradation of kastanozem soils and the possibility of its application for monitoring and forecasting the condition.

Description of the main research results.

The study established that the current state of kastanozem soils in the southern Kostanay region is influenced by a combination of climatic, soil, and anthropogenic factors, the interaction of which determines soil degradation processes and the transformation of agricultural landscapes.

It was established that kastanozem soils in the southern Kostanay region function under conditions of pronounced climatic instability and long-term anthropogenic impact, which determine their current degraded state.

Climate analysis for 2010–2020 revealed significant moisture variability: precipitation in dry years decreased to 192.3–236.4 mm, while in wet years it increased to 303.1–414.1 mm. Soil temperatures at a depth of 0–20 cm ranged from 107.0 to 124.0°C. Droughts in 2012, 2016, 2020, and 2023 were identified as having a significant impact on reduced vegetation productivity and increased degradation.

Soil studies revealed a decrease in humus content from 2.4% to 1.5%, indicating organic matter degradation. The soils are characterized by pronounced salinization: salt content reaches 0.536–0.592% in the lower horizons. SO_4^{2-} and Na^+ predominate (60–80% of anions), with sodium concentrations at depths greater than 40 cm reaching 6.56–9.92 mg-eq/100 g, creating a toxic environment.

The vegetation cover is represented by weeds and xerophytic species with a projective cover of 30–80%. An increase in xerophytes and a decrease in agrophytocenoses have been noted with increasing fallow land.

During the years of research, the productivity of plant phytomass influenced the yield of wheat and barley in fields No. 35A and No. 12, where yields reached 14.67–11.58 c/ha. In field No. 7, the yield decreased to 3.61 c/ha due to the reduction in plant phytomass. In fallow field #59, productivity remains relatively stable (33.8–39.2 centners/ha).

NDVI values ranged from 0.11–0.17 during dry periods to 0.30–0.63 in climatically favorable years. The lowest values were recorded in Field No. 7 (0.13–0.18), whereas the highest values were observed in Field No. 59 (up to 0.45), reflecting different degrees of land degradation.

The main factors contributing to degradation are salinization, sodium accumulation, humus depletion, climatic aridity, and land-use patterns. With a climate index of I_{clim} = 0.5745, it was established that soil and anthropogenic factors play a leading role. The developed integrated degradation index (LDI) enabled a quantitative assessment of the state of agricultural landscapes: fields #35A and #7 are the most degraded (0.62–0.63), field #12 is moderately degraded (LDI ≈ 0.54), and field #59 is relatively stable (≈ 0.37).

Justification of novelty and importance of the obtained data. The scientific novelty of this study lies in its integrated approach to assessing the condition of kastanozem soils in the southern Kostanay region, considering long-term climate change, vegetation characteristics, and anthropogenic impacts. For the first time in this region, a comprehensive analysis of soil-climatic factors and vegetation cover was conducted, making it possible to identify the main causes of degradation and the patterns of post-agrogenic successional processes. Relationships were established between vegetation productivity indicators, the

NDVI vegetation index, and long-term meteorological conditions. Based on the data obtained, a model for the integrated assessment of kastanozem soil degradation (LDI) was developed, enabling quantitative characterization of degradation levels for monitoring and forecasting purposes.

Practical significance. The practical significance of the study lies in the fact that the obtained results can be used in soil science and agronomy for a comprehensive assessment of the condition and fertility of kastanozem soilsin the southern Kostanay region. The developed Land Degradation Index (LDI) model allows for a quantitative assessment of the degree of soil degradation, taking into account its morphological, physicochemical, and biological characteristics, as well as climatic conditions and vegetation status.

The proposed approach can be used to monitor degradation processes and assess the resilience of soil systems under anthropogenic impact, as well as for agricultural land use planning, the development of adaptive agricultural technologies, and cadastral land valuation. The study results make it possible to justify rational land use, predict crop yields, and develop measures to improve and restore the fertility of kastanozem soils.

The use of remote sensing data (NDVI), long-term climate indicators and vegetation characteristics improves the accuracy of soil condition diagnostics and provides a scientific basis for the development of adaptive agricultural technologies and sustainable land management systems.

Relationship of the dissertation to other research projects. This dissertation was completed within the framework of research project AP05133791, “Improvement of the Methodology for Analyzing and Assessing the Effectiveness of Approaches to Increasing the Cadastral Value of Agricultural Land in the Republic of Kazakhstan,” implemented during 2018–2020 under Subprogram 102, “Grant Financing of Scientific Research,” within Program No. 217, “Science Development,” of the Ministry of Science and Higher Education of the Republic of Kazakhstan, in the priority research area “Sustainable Development of the Agro-Industrial Complex and Safety of Agricultural Products”.

Description of the doctoral student's contribution to the preparation of each publication. Based on the results of this thesis, eight scientific articles have been published, including two articles in international scientific journals indexed in the Scopus database; two articles in journals recommended by the Committee for Quality Assurance in Science and Higher Education of the Ministry of Science and Higher Education of the Republic of Kazakhstan; one article in a journal included in the Russian Science Citation Index (RSCI) database; three articles in international conference proceedings; and one registered copyright.

Thesis Length and Structure. The dissertation is presented on 146 pages of computer text and consists of an introduction, four sections, a conclusion, and appendices. Thesis materials are illustrated with 41 tables and 21 figures, presented in the form of photographs, graphic diagrams, and charts. The list of references includes 113 bibliographic titles.