

ABSTRACT

of the dissertation submitted for the degree of Doctor of Philosophy (PhD) in the specialty 8D07302 – “Geodesy”

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POST-CLASSIFICATION ANALYSIS OF LAND-USE DYNAMICS IN SELECTED DISTRICTS OF THE KARAGANDA REGION

Relevance of the Research. The contemporary dynamics of environmental management under conditions of increasing anthropogenic pressure, climate change, and intensive landscape transformation necessitate the development of high-precision methods for land-use monitoring. Spatio-temporal changes in land cover directly affect ecosystem stability, local climate conditions, the state of pastures and forest areas, as well as socio-economic processes in the regions. For the territories of Central Kazakhstan, including the Karagandy Region, significant fluctuations in natural conditions, pronounced climatic contrasts, and intensive economic development create an urgent need for comprehensive research.

Remote sensing technologies and geo-analytical methods serve as key tools in such studies, providing independent and objective sources of data for identifying long-term trends. Considering that satellite observations allow the assessment of land-cover transformations over extended periods, their use is particularly important for analyzing the sustainability of land resources and forming scientifically grounded recommendations.

The **object of the study** is the land-use system of the Karagandy Region, viewed as a set of spatially distributed land categories subject to natural and anthropogenic changes.

The subject of the study comprises the spatio-temporal patterns of land-use dynamics during 2000–2024, the methods for detecting these patterns using Landsat satellite data, and the tools of post-classification analysis and modelling.

The **aim of the research** is to improve the accuracy of land-use monitoring through the development and testing of a post-classification analysis methodology for multi-year satellite data and through the construction of spatio-temporal models reflecting the transformation of land-use categories.

The **main idea of the study** is the comprehensive integration of remote sensing data, geoinformation analysis, digital elevation models, and socio-economic indicators to identify the factors driving long-term land-cover changes, as well as the development of harmonized classification, accuracy assessment, and spatial forecasting models.

Justification of the Novelty and Importance of the Results. The scientific novelty lies in the development of a post-classification analysis methodology that has, for the first time, made it possible to identify the spatio-temporal regularities of land-use change in districts of the Karagandy Region. The integration of natural and socio-economic factors enabled the establishment of causal relationships underlying land-cover transformations; a system for evaluating the quality of classification

models was proposed; and predictive models of further land-cover development were developed.

The importance of the obtained results is determined by their applicability to solving problems of rational land management, improving regional planning, and enhancing the efficiency of land-monitoring systems.

Research Objectives:

- to review domestic and international studies on land-use dynamics and satellite-based classification methods;
- to identify optimal algorithms for processing and classifying multispectral data;
- to develop a post-classification analysis methodology for multi-year Landsat data;
- to produce land-use maps for 2000–2024 and conduct their comparative analysis;
- to identify spatio-temporal patterns of land-use change using transition matrices and development models;
- to integrate natural and socio-economic indicators to determine the driving factors of land-use change;
- to develop a system for assessing the quality of classification models;
- to construct predictive models of land-use development.

Key Provisions Submitted for Defence.

1. The developed post-classification analysis methodology ensures high accuracy and reliability in studying land-use dynamics.
2. The use of satellite data and geoinformation analysis makes it possible to identify spatio-temporal regularities of land-use change.
3. The implementation of a metrological control system guarantees the reliability of the obtained data and their adaptation to regional conditions.
4. The research findings can be used to support strategies for sustainable development of the Karagandy Region.

Research Methods. The study uses multi-year Landsat satellite data, which provide the opportunity to analyse long-term land-use trends. To account for topographic factors, the SRTM digital elevation model was applied, supplying essential elevation parameters.

Integration of satellite imagery, orthomosaics, and thematic layers was performed within geographic information systems, enabling the formation of a multi-layer spatial database and the correct interpretation of results.

Machine-learning methods were used for classification, which improved the accuracy of land-cover class identification and enabled the analysis of dynamics using transition matrices and LULC models. The reliability of the results was ensured through metrological control and validation based on reference data.

Practical Significance. The developed methodology provides objective information on long-term processes of land degradation, transformation, and restoration, and enhances the quality of spatial change analysis in rural territories. The results can be applied to improve land-resource management mechanisms,

evaluate state policy effectiveness, and justify decisions in agro-industrial development.

The post-classification methodology has been integrated into the scientific and technical projects of the Ministry of Agriculture of the Republic of Kazakhstan and can be used in national monitoring systems, sectoral information platforms, as well as in educational programmes in geodesy, cartography, and remote sensing.

Alignment with Scientific Priorities and State Programs. The research aligns with the priority scientific directions of the Republic of Kazakhstan in the fields of geodesy, cartography, natural-resource monitoring, spatial-data digitalization, and sustainable development. The work corresponds to national strategies for the modernization of the agricultural sector and digital transformation, and it was carried out within the framework of scientific and technical programs of the Ministry of Agriculture of the Republic of Kazakhstan:

- BR10764919 “Study of the impact of state agricultural policy on the development of cooperation processes in the agro-industrial complex, sustainable development of rural areas, and ensuring food security”;

- BR22886730 “Formation of the agricultural spatial-data infrastructure of the Republic of Kazakhstan based on Web 2.0 technologies and principles.”

The obtained results contribute to the development of the national spatial-data infrastructure and to increasing the efficiency of state land monitoring.

Justification and Reliability of Results and Conclusions. The reliability of the research findings is ensured by the theoretical justification of the applied methods, the use of multi-year satellite data, and extensive computer modelling. The correctness of the conclusions is confirmed by experimental verification, statistical processing, and calculations performed using specialized software packages. The main provisions of the dissertation have undergone scientific review, have been published in peer-reviewed journals indexed in international databases, and have been presented at international scientific conferences, which confirms their scientific relevance and objectivity.

Scope and Structure of the Dissertation. The dissertation consists of an introduction, four main chapters, a conclusion, and appendices. The total volume is 152 pages of typescript and includes 84 figures, 11 tables, a list of 149 references, and 7 appendices.

Description of the Main Research Results:

- a unified multi-year Landsat satellite data archive (2000–2024) has been compiled and prepared for further processing;

- a post-classification analysis methodology has been developed and tested, including classification, validation, and detection of land-cover change;

- land-use maps have been produced and key trends in the transformation of land categories in the districts of the Karagandy region have been identified;

- spatio-temporal regularities of land-use redistribution have been determined using transition matrices and statistical analysis;

- satellite data have been integrated with a digital elevation model, and climatic, demographic, and socio-economic indicators to identify the drivers of change;

- a metrological system for evaluating the quality of classification models has been developed;
- predictive land-use development models reflecting potential scenarios of spatial transformation have been constructed;
- the results of the research have been applied in scientific and technical projects of the Ministry of Agriculture of the Republic of Kazakhstan and can be utilized in monitoring and educational programs.

Application Area

The results of the research can be applied in state and departmental land-monitoring systems, in the development of regional programs for sustainable development, environmental planning, and rational land use. The generated land-use classification maps, dynamic models, and predictive scenarios can be used by government agencies, design organizations, research institutions, and educational bodies for assessing land-resource conditions, analyzing land-cover change, and planning measures for the development of rural territories.

Contribution of the Doctoral Candidate to Each Publication

During the approbation and publication of the dissertation results, scientific articles and conference materials were prepared and published in outlets of various levels, including Q1 Scopus journals, international conferences, and registered copyright works.

Articles in Scopus-indexed (Q1) Journals

1. Untangling the Integral Impact of Land Use Change, Economic, Ecological and Social Factors on the Development of Burabay District (Kazakhstan) during the Period 1999–2021 // *Sustainability*, 2023, 15(9):7548.
The doctoral candidate contributed by processing satellite data, integrating socio-economic indicators, developing the factor-interaction model, and participating in the writing of the article.
2. Analysis and Prediction of Land Use/Land Cover Changes in Korgalzhyn District, Kazakhstan // *Agronomy*, 2024, 14(2), 268.
The doctoral candidate developed the Landsat-data classification methodology, constructed predictive models, and conducted the spatio-temporal analysis of land-use dynamics.
3. Ecosystem Health Assessment of the Zerendy District, Kazakhstan // *Sustainability*, 2025, 17(1), 277.
The doctoral candidate contributed by processing spatial data, calculating ecological indices, analyzing degradation factors, and participating in the development of the final ecosystem-assessment model.

Publications in Journals and International Conferences Indexed in Scopus (Q2–Q4).

1. Assessment of the accuracy of the geometric scheme of GCPs when creating DSM using UAV // *News of NAS RK. Series of Geology and Technical Sciences*, 2025.
The doctoral candidate processed UAV data, participated in accuracy assessment of georeferencing, and contributed to the DSM-modelling calculations.

2. Spatiotemporal analysis and identifying the driving forces of land use change in the Abay district // E3S Web of Conferences, GI-2024.

The doctoral candidate performed satellite-data processing, constructed models of land-use driving forces, and conducted the analytical interpretation of results.