

ANNOTATION

Dissertation for the degree of doctor of philosophy (PhD) in the specialty «6D071100-Geodesy» by Muratbek Kudaibergenov on the topic: «Geodetic substantiation of geoecological zoning of the territory according to the degree of danger of gravitational processes»

Assessment of the Current State of the Scientific or Scientific–Technical Problem under Consideration

One of the main directions of regional geoecology is the study and zoning of natural and anthropogenically transformed ecosystems formed within a specific territory. Each of these ecosystems is characterized by particular ecological and geological parameters, as well as by specific features of spatial distribution. Geoecological zoning is of particular importance for the rational use of natural resources, the assessment and forecasting of ecological phenomena, and the identification of territories that are hazardous from a geodynamic perspective. The identification of hazardous natural processes and the assessment of territorial resistance to technogenic impacts require comprehensive research.

Each morphostructure of the Earth's surface is distinguished by its inherent ecological characteristics, while its lithological basis determines the specific functioning of natural systems and their level of resistance to external influences.

Rationale for the Development of the Research Topic and Initial Data

Under conditions of contemporary climate change and increasing technogenic pressure, the importance of geoecological zoning is growing significantly. It is becoming an important tool for the effective management of natural resources and for ensuring the adaptive resilience of territories to ecological and geodynamic risks. Such zoning is especially relevant for the territory of the Talgar River, located near the city of Talgar in Almaty Region, since this area belongs to mountainous territories characterized by high seismic activity and an increased probability of landslide development.

From the standpoint of ensuring the safety of the population and infrastructure, the identification of areas with a high probability of gravitational phenomena is of particular importance. In addition, agricultural and recreational zones associated with river floodplains and water bodies are exposed to factors such as changes in the hydrological regime, soil erosion, and flood processes. Under such conditions, geoecological zoning serves as a scientific basis for developing adaptation and preventive measures aimed at reducing the negative impact of natural processes, ensuring rational environmental management, and minimizing the consequences of anthropogenic influence on regional ecosystems.

The development of the research topic is based on a comprehensive study of landslide processes as one of the key directions of geoecological analysis and as a factor in the formation of specific natural–territorial complexes. One of the main tasks in the ecological study of such processes is the analysis of the formation and development of landslide landscapes. The specific relief and hydrological regime of

territories affected by landslide activity make it possible to consider these areas as distinct ecosystem formations.

Landslide landscapes are characterized by pronounced morphostructural differentiation, including zones of detachment, transit, and accumulation of displaced masses. The relief – forming effect of landslide processes is especially evident on slope areas, where water flows cause surface erosion and contribute to the formation of smaller repeated landslides. These processes lead to changes in slope configuration, the development of erosion, subsidence phenomena, and local deformations, including in areas adjacent to the river channel. In certain cases, bank collapse processes are recorded, causing significant transformation of channel morphology.

Information on the Scientific and Technical Level of the Planned Development, Patent Research, and Conclusions Based on Them

The scientific and technical level of the planned development involves the integrated use of modern geodetic, geoinformation, unmanned aerial vehicle, and neural network technologies for the geodetic substantiation of geoecological zoning of a territory according to the hazard level of gravitational processes. Within the framework of the study, high-precision geodetic observations, GNSS technologies, materials obtained using unmanned aerial vehicles, digital elevation models, and spatial analysis methods were applied to identify, assess, and zone territories prone to gravitationally hazardous processes. Comprehensive processing, analysis, and integration of the obtained data using neural network models were also carried out.

Information on the Metrological Support of the Dissertation

The reliability of the obtained results is confirmed by the set of research methods applied in the geodetic substantiation of geoecological zoning of the territory according to the hazard level of gravitational processes.

During field investigations, high-precision geodetic instruments, satellite receivers, and unmanned aerial vehicles were used. These instruments had undergone state metrological verification and complied with the current regulatory requirements of the Republic of Kazakhstan. All measurement and surveying works were carried out in accordance with technical regulations and the rules for operating the instruments.

The units of measurement used in the work were adopted in accordance with the metrological requirements of the International System of Units (SI) and current standards. The use of certified equipment verified instruments, and modern software-methodological tools ensures the high reliability, accuracy, and practical significance of the research results.

Relevance of the Research Topic

There are approximately 85,022 rivers in Kazakhstan, the vast majority of which – 84,694 are less than 100 km long. The number of watercourses with a length of 100 to 500 km is 305, while the number of rivers ranging from 500 to 1,000 km is 23. According to hydrographic research data, the total number of rivers longer than 10 km is approximately 8,000, of which about 7,000 are permanent watercourses exceeding the 10-kilometer threshold.

The information provided confirms the relevance of the selected research topic, since a significant part of the country's river network belongs to internal closed basins. One such watercourse is the Talgar River, which is 117 km long and has a catchment area of 444 km². The river originates from the Talgar Glacier and flows into the Kapshagay Reservoir. The main Talgar River is formed in the foothill part of the region by the confluence of two small tributaries, the Left Talgar and the Right Talgar.

The waters of the river are used for agricultural purposes, water supply, and by energy enterprises. The city of Talgar, as well as the settlements of Avat, Novoalekseevka, Zhanazhar, and others, are located along the river. In some cases, mudflow processes are observed in the river basin alongside landslide processes.

Landslide processes pose a significant hazard, as they directly or indirectly affect the natural environment, the economy, and the social well-being of the population; in some cases, their activation may lead to human casualties and material damage.

In this regard, the geodetic substantiation of geoecological zoning of a territory according to the hazard level of gravitational processes is an urgent scientific and technical problem and a complex research task. A comprehensive study of these processes and their consideration are of particular importance for preventing negative consequences. The dissertation devoted to the geodetic substantiation of geoecological zoning according to gravitational hazard is especially relevant in terms of preventing technogenic emergency phenomena caused by the development of landslide processes within riverbank zones.

Scientific Novelty of the Research Topic

A comprehensive approach to geoecological zoning according to the hazard level of gravitational processes has been developed for the Talgar River territory based on the integration of geodetic, satellite, geoecological, and engineering – geological data.

For the first time, a comprehensive methodology for the long-term analysis of gravitational processes has been developed for the Talgar River territory based on the integration of spatio-temporal geodetic and satellite data with geoecological and engineering-geological indicators.

Aim of the Research

The aim of the research is to provide scientific substantiation for geoecological zoning of a territory based on the assessment of the hazard level of gravitational processes using geodetic, geoinformation, and satellite data.

Object and Subject of the Research

The object of the research is gravitationally hazardous processes and the geoecological conditions formed within their development area in the territory of the Talgar River.

The subject of the research includes methods and technologies for geoecological zoning of a territory according to the hazard level of gravitational processes based on the use of geodetic, satellite, geoinformation, unmanned aerial vehicle, and neural network data.

Research Objectives

To achieve the stated aim, the following objectives were addressed in the dissertation:

1. To analyse methods for assessing and forecasting gravitational processes, taking into account the geomorphological and anthropogenic features of the Talgar River territory.
2. To determine and analyse morphometric relief indicators, including slope, aspect, and surface curvature, for the geodetic substantiation of geoecological zoning.
3. To develop a geoecological zoning map of the study area according to the hazard level of gravitational processes based on the results of integrated monitoring and neural network analysis.
4. To establish the geodetic basis of the research by designing and creating a specialized horizontal and vertical control network within the study area, as well as performing its adjustment based on static GNSS observations with reference to the international ITRF system.
5. To assess the spatio-temporal dynamics of gravitational processes based on the integration of geodetic, geoinformation, satellite data, and neural network modelling.

Research Methods

A set of research methods was applied in the dissertation to achieve the aim and address the stated objectives.

Methods of satellite data processing were used to assess gravitationally hazardous areas, including photogrammetry with an unmanned aerial vehicle, satellite monitoring based on Sentinel-2 data, and analysis of Sentinel-1 radar data using the InSAR method. Pearson correlation analysis was applied for the quantitative assessment of the obtained results. During the integrated processing of spatial data and the classification of hazard levels, an artificial neural network with an $11 \times 9 \times 1$ architecture was used, on the basis of which a geoecological zoning map was developed. The accuracy and reliability of the research results were verified using validation and comparative analysis methods.

As a result of the comprehensive data analysis, hazardous areas prone to the development of gravitational processes were identified. Based on the use of a patented innovative device – a permanent ground benchmark (Patent No. 4700) – high-precision tacheometric surveys were carried out using South G4, South G6, and Leica TC 1201 instruments, along with GNSS satellite monitoring. Geoinformation analysis methods were widely applied during the research; topographic maps, statistical data, and meteorological data were processed. In addition, based on the digital elevation model (DEM), morphometric relief characteristics were determined, including slope, relief form, and aspect.

Scientific Provisions Submitted for Defence

1. The processing and integration of long-term spatial information, including satellite and geoinformation data, make it possible to identify zones of anomalous deformation activity and determine the boundaries of landslide-prone areas with high accuracy.

2. The application of the patented author's model of a permanent ground benchmark (Patent No. 4700) ensures an increase in the stability of the control network and the accuracy of monitoring measurements under conditions of complex mountainous relief.

3. The use of GIS analysis and neural network modelling methods to determine the hazard level of gravitational processes serves as the basis for compiling a geoeological zoning map of hazardous territories in the Talgar District.

Practical Significance

The practical significance of the dissertation is determined by the possibility of applying the obtained results in geoeological zoning of the Talgar River territory according to the hazard level of gravitational processes, in identifying hazardous areas, organizing monitoring, and developing measures for the prevention of natural hazards.

The results of the research may be used in various fields of activity, in the Department of Land Relations of the city of Almaty, as well as in domestic and international research organizations of the relevant profile. This will contribute to economic development and to improving the safety of national infrastructure.

Theoretical Significance

The theoretical significance of the study lies in the development of methods for the geodetic substantiation of geoeological zoning of a territory according to the hazard level of gravitational processes, as well as in the improvement of approaches to assessing hazardous territories based on the integrated use of geodetic, satellite, geoinformation, unmanned aerial vehicle, and neural network data.

The developed methodology may be used to improve the accuracy of geoeological zoning according to the hazard level of gravitational processes in other regions with similar natural and geodynamic conditions.

Personal Contribution of the Author

The personal contribution of the author consists in formulating the aim and objectives of the research, preparing the initial information base, carrying out computational and analytical work, processing geodetic and satellite observation data, analysing and scientifically interpreting the obtained results, developing a geoeological zoning map according to the hazard level of gravitational processes, and preparing scientific articles and the text of the doctoral dissertation.

Publications and Approbation of the Work

The following works have been published on the topic of the dissertation research:

1. An article entitled «Predictive System for Road Condition Monitoring based on Open Climate and Remote Sensing Data – A Case Study with Mountain Roads» was published in *Engineered Science*, Vol. 28, Issue 1081, 2024, DOI: <https://10.30919/es1081>, Q1.

2. An article entitled «Application of Artificial Intelligence in Landslide Susceptibility Assessment: Review of Recent Progress» was published in *Remote Sensing*, Vol. 18, Issue 11, 2025, DOI: <https://doi.org/10.3390/rs17010034>, Q1.

3. An article entitled «Application of the Wavelet Transformation Theory in the Algorithm for Constructing a Quasigeoid Model» was published in *Naukovyi*

Visnyk Natsionalnoho Hirnychoho Universytetu, 2022, DOI:
<https://doi.org/10.33271/nvngu/2022-4/123>, Q3.

Structure and Scope of the Dissertation

The dissertation consists of an introduction, a literature review, a description of the research object and methods, a section presenting and discussing the research results, a conclusion, and a list of references.