

ANNOTATION

the dissertation work of Sagynbayeva Ainur Bagdatkyzy on the topic:
«The use of GIS technologies and aerospace methods in the study of the state and changes in the dynamics of pine forests in Kazakhstan (on the example of the state natural forest reserve «Semey ormany»)» submitted for the degree of
Doctor of Philosophy (PhD) under the educational program
8D08302 – «Forest resources and forestry»

Relevance of the research topic: The relevance of studying the condition and dynamics of changes in pine forests in Kazakhstan is directly linked to the country's ecological and economic development strategies. This research aligns with the following state initiatives:

Within the framework of the «Digital Kazakhstan» state program, the use of GIS technologies and aerospace methods for studying pine forests corresponds to Kazakhstan's key digitalization policies. These technologies modernize the management system of natural resources, enabling the automation of forest monitoring and management.

The national project «Green Kazakhstan»(2021–2025) aims to restore forest areas and preserve natural ecosystems. Research into the condition of pine forests using aerospace methods contributes to the effective management of the ecological functions of forested areas.

In the context of implementing the UN Sustainable Development Goals, the protection and restoration of forests are directed toward maintaining the sustainability of natural ecosystems. The data obtained through this research will support achieving these goals.

The «Development program for forestry in the republic of Kazakhstan (2021–2025)» emphasizes the use of modern digital technologies in forest monitoring and management. The research results will serve as a foundation for fulfilling these objectives.

Studying the condition of pine forests using GIS and aerospace methods plays a crucial role in ensuring the country's sustainable development, aligning with Kazakhstan's ecological and digital transformation programs. This research directly contributes to the preservation and effective management of forest resources, adaptation to climate change, and the rational use of natural resources.

The purpose of the dissertation research: To study the condition of pine forests and the dynamics of changes in forest cover in Kazakhstan using GIS technologies and remote sensing methods (based on the example of the «Semey Ormany» state natural forest reserve).

Research objectives:

- Determine the condition and dynamic changes of pine forests using the FCD method;
- Investigate changes by applying the NDVI index;
- Compare the FCD and NDVI indicators based on the research results;

- Assess the condition of pine forest areas in the territory of the Zhanasemei branch of the State Natural Forest Reserve “Semey Ormany” before and after the fire, as well as the process of their post-fire restoration;
- Analyze the causes of dynamic changes in the pine forest cover of the Semey Ormany reserve based on the platforms «Google Earth, Global Forest Watch, GLAD Forest Alerts».

Main provisions (proven scientific hypotheses and other findings representing new knowledge): Justification for using GIS technologies and aerospace methods to determine the condition and dynamics of pine forest changes:

GIS technologies and aerospace methods (satellite imagery) enable rapid acquisition of accurate spatial data about the state of pine forests. It has been proven that multispectral and hyperspectral data are effective for determining forest canopy density and degradation processes.

The FCD model, combining remote sensing and ground-based data, enables predictions of dynamic changes in forests. The model has demonstrated its efficiency in assessing forest degradation risks and recovery levels.

Development of recommendations for forest management based on GIS data integration:

Recommendations have been developed for implementing a system of early detection of changes in forest ecosystems, including the use of drones and real-time satellite monitoring.

Development of methodological approaches to determine the condition and dynamics of pine forest changes:

A comprehensive assessment algorithm has been developed to determine the condition and dynamics of pine forests. Forest canopy density maps (FCD maps) and NDVI assessment maps have been created, covering data collection, processing, and analysis stages using modern GIS programs and aerospace technologies.

The universality of the methodology has been proven, and its applicability to other forest ecosystems in Kazakhstan with similar natural conditions has been demonstrated.

Research methods: The methodological basis of the research involved modern remote sensing methods and GIS technologies to assess and analyze the dynamic changes in pine forest cover. The following methods were used:

FCD (Forest Canopy Density) Method:

Developed in the 1990s by scientists from the Japanese Aerospace Research Agency and experts from Thailand. Used to assess the spatial and temporal changes in forest cover and describe their dynamics. Purpose: To monitor and describe changes in forest density caused by anthropogenic and natural factors.

NDVI (Normalized Difference Vegetation Index) Method:

Based on the development of J.W. Rouse and used to assess forest cover conditions. Purpose: To quantitatively assess the recovery rates of green vegetation in forest areas after fires.

NBR (Normalized Burn Ratio) Method:

Developed by Christopher Key and Nicholas Benson for analyzing the impact of fires on vegetation and soil cover. Purpose: To spatially and quantitatively determine the effects of fires on forest cover.

Use of Remote Sensing Data: Data from satellite platforms such as Landsat, Sentinel-2, and MODIS were used. Purpose: To monitor the long-term dynamics of forest cover with high precision, create spatial models, and track changes over time.

Application of GIS Technologies: Used for processing, visualizing, and mapping research results. Purpose: To visually represent changes in forest ecosystems and determine their spatial characteristics.

Use of Space Platforms: Platforms such as «Global Forest Alerts», «Google Earth», «Global Forest Watch» and «EO Browser» were utilized based on remote sensing and space monitoring data. Purpose: To promptly and accurately identify changes in forest ecosystems.

Description of the main research results:

Application of the Forest Canopy Density (FCD) Method: Using the FCD method to determine the condition and dynamics of pine forests from 2008 to 2023 revealed significant changes in the pine forest areas within the Semey Ormany State Natural Reserve. FCD, applied using Landsat satellite imagery data, enabled the analysis of change dynamics across several indices (AVI, BI, SI).

Application of the Normalized Difference Vegetation Index (NDVI): NDVI was used to analyze changes in the pine forest cover of the Semey Ormany Reserve over 15 years (2008–2023). Positive changes in vegetation were observed, including an increase in areas with high vegetation density and a decrease in non-vegetated areas. These results confirm the restoration of ecosystems and the effectiveness of forest improvement measures, emphasizing the importance of continuing forest conservation and restoration efforts to promote sustainable forest development.

Comparison of FCD and NDVI Indicators: A comparison of the FCD and NDVI methods from 2008 to 2023 revealed similar trends in pine forest changes:

NDVI provides a general view of vegetation conditions over large areas and allows tracking the dynamics of not only forests but also other vegetation types. However, its limitation lies in its inability to accurately assess tree canopy density, especially in dense forests.

FCD, on the other hand, is more accurate for assessing forest areas, as it is specifically designed to analyze tree canopy density and better reflects changes in forest structure. Its drawback is the exclusion of other vegetation types.

Analysis of pine forest density in the Zhanasemey branch using the NBR index: The density of pine forests before and after a fire (2007 and 2008) in the Zhanasemey Branch of the Semey Ormany reserve was analyzed using the NBR index to evaluate the recovery process. A significant improvement in the recovery of pine forests after the fire was identified. Remote sensing data and GIS methods confirmed that post-fire recovery occurs gradually, with an increase in vegetation density and a reduction in non-vegetated areas.

Analysis of forest cover dynamics and their causes: Using platforms such as «Google Earth», «Global Forest Watch (GFW)» and «Global Land Cover» forest cover changes were analyzed based on satellite data:

The causes of forest destruction and restoration were identified.

It was determined that dense forest cover is rare in the western and southern regions. The reduction in forest density and the expansion of sparse areas, particularly in the southeastern part of the Semey Ormany Reserve, indicate forest cover degradation.

Justification of the novelty and significance of the results: The novelty of the research lies in the fact that the principles of applying remote sensing methods and GIS technologies for studying the condition of forest areas within the «Semey Ormany» state natural forest reserve have been substantiated for the first time.

The analysis of the past 15 years of changes in the condition of pine forests within the «Semey Ormany» reserve revealed quantitative and qualitative changes in the structure of pine forests under the influence of natural and anthropogenic factors, including fires and illegal logging.

The FCD method was applied for the first time to assess the dynamics of forest canopy changes within the «Semey Ormany» reserve. Based on the obtained data, an FCD map illustrating the dynamics of forest canopy changes over the past 15 years was created.

The recovery process of forest cover in areas affected by fires was monitored using NDVI and NBR indices. The annual recovery process of forest cover was determined, and a map analyzing the NDVI index for assessing the state of forest cover was developed.

Relevance to the directions of science development or state programs: The research topic on the application of GIS technologies and aerospace methods to study the condition and dynamics of changes in pine forests in Kazakhstan aligns with several state programs and strategic documents. This direction corresponds to the country's priorities in ensuring environmental sustainability, forest resource management, and environmental protection, specifically:

«Kazakhstan's strategy for achieving carbon neutrality by 2060» restoring and expanding forest areas, as well as monitoring forests, is a key focus of the strategy for increasing carbon sequestration potential. Research on the condition of pine forests using GIS and aerospace methods contributes to assessing the carbon cycle and preserving ecosystems.

«forest management development program of the republic of Kazakhstan for 2021–2025». The program addresses the digitalization of forests, monitoring, and the introduction of advanced technologies. GIS and aerospace methods play a vital role as innovative tools in forest management.

The state program «Digital Kazakhstan». The use of digital technologies in forest resource management aligns with the program's focus areas on «Digitalization of the Economy» and the «Digital Ecosystem». GIS technologies and aerospace methods enable the collection and analysis of precise data, as well as improvements to monitoring systems.

Description of the doctoral candidate's contribution to each publication: As part of the dissertation research, the candidate was directly involved in obtaining research results, analyzing them, and drawing conclusions. Additionally, the author

contributed to publishing the research findings in both domestic and international journals.

Based on the results of the research, 10 articles were published, including 4 articles in scientific publications recommended by the Committee for education and science control of the Ministry of Science and Higher Education of the Republic of Kazakhstan, and 1 article in the Scopus database. Additionally, 5 articles were presented at international and national scientific conferences.

Structure and scop of the dissertation: The structure of the dissertation consists of four main chapters, a conclusion, and a list of references, which includes 165 sources. To demonstrate the validity of the research results, the dissertation contains 62 figures, 32 tables, and 4 appendices with supplementary materials.