

REVIEW

on the dissertation thesis entitled

"Spatial analysis and assessment of the state and ecosystem services of ecosystems in the upper forest boundary of Rila"

for awarding the scientific and educational degree "PhD" in the scientific field 4. Natural sciences, mathematics and informatics, professional field 4.3. Biological sciences, scientific specialty "Ecology and ecosystem protection",

Author: Kostadin Marinov Katrandzhiev

Scientific supervisor: Assoc. Prof. Dr. Svetla Valeva Bratanova-Doncheva **Scientific**

consultants: Prof. Dr. Stoyan Nedkov and Prof. Dr. Nesho Chipev **Reviewer:**

Prof. Dr. Miglena Kircheva Zhiyanski, Institute of Forestry - Bulgarian Academy of Sciences, professional field 6.1. "Plant Sciences", scientific specialty "Soil Science", appointed as a member of the Scientific Jury by Order No. 96/23.12.2024 of the Director of IBER-BAS

BRIEF BIOGRAPHICAL DATA OF THE CANDIDATE

Kostadin Marinov Katrandzhiev holds a bachelor's degree in ecology and a master's degree in ecological management, acquired at the New Bulgarian University (2012). From 2016 to 2018 he was a full-time PhD student in the "Ecosystem Research" department at the Institute of Biodiversity and Ecosystem Research of the Bulgarian Academy of Sciences (IBER-BAS), where he developed the dissertation work, the subject of this review. After completing the term of the full-time doctoral studies (until 31.12.2018), he was discontinued with the right to defend his dissertation. The dissertation was discussed and directed for defense at an extended session of the "Ecosystem Research, Ecological Risk, and Conservation Biology" department of the Institute of Biodiversity and Ecosystem Research, BAS, held on October 29, 2024.

During his doctoral studies, the candidate participated in specialized training and courses (remote sensing methods, GIS, statistical analysis), which contributed to his professional development. Between April 2019 – January 2020, he completed specialized training at the Institute for Space Research and Technology (ISRT) at BAS, related to satellite data processing. He has successfully passed examinations in English language proficiency and computer literacy at the Central Training Center of BAS. The total number of credits earned during his doctoral program is 474.

The submitted set of documents complies with Article 39 (1) of the Regulations on the Conditions and Procedures for the Acquisition of Scientific Degrees and for Holding Academic Positions at IBER-BAS.

The dissertation consists of 58 pages, along with 87 pages of compiled publications on the dissertation topic, and includes 10 main sections, 5 tables, and 17 figures. The bibliography contains 73 references in both Latin and Cyrillic scripts.

SIGNIFICANCE OF THE RESEARCHED PROBLEM IN SCIENTIFIC AND SCIENTIFIC APPLIED RELATIONS

Studies of high-mountain ecosystems are of interest to modern ecological science and contribute to enriching our understanding of the complex dynamics of natural systems. From a scientific perspective, analyzing structural and functional characteristics of ecosystems in highmountain regions contributes to the study of the interaction between biotic and abiotic components of the environment in the context of climate change, helping to create more accurate and comprehensive models of ecosystem dynamics. At the same time, determining the responses of high-mountain ecosystems to climatic factors provides valuable insights into their adaptation mechanisms and resilience, which is crucial for ecological science.

From a scientific and applied aspect, the extended analysis, integrating geoinformation technologies, climatology and ecology, represents the application of an innovative approach and provides a scientific basis for the assessment of ecosystem services, with a view to the strategic planning and management of high-mountain territories. The application of remote sensing methods and GIS technologies enables regular and efficient monitoring of hard-toaccess and dynamic ecosystems, which is of particular importance for the timely identification of negative trends and for taking adequate measures.

GOAL OF THE DISSERTATION

The goal of the thesis is a critical analysis and assessment of the functional state of a defined highland ecosystem in the southwestern parts of the Rila National Park, as well as an assessment of its capacity to provide selected ecosystem services, using remote methods and geoinformation technologies.

To achieve the defined goal, the following scientific tasks were performed in the dissertation:

1. A structural-functional characteristic of a selected and defined highland ecosystem on the territory of the Rila National Park was prepared;
2. An analysis and assessment of existing data were performed;
3. An assessment of the functional state of the highland ecosystem was made using vegetation indices using remote sensing (orthophoto, satellite), GIS-based and other methods;
4. A selection was made and ecosystem services were assessed within the territorial scope of the defined "highland ecosystem".

STRUCTURE OF THE DISSERTATION

The dissertation is structured in the form of a main text supported by three (3) complied publications which demonstrate the originality and quality of the scientific work.

Publications:

"APPLICATION OF REMOTE SENSING FOR HIGH MOUNTAIN ECOSYSTEM CONDITION ASSESSMENT (SOUTH WEST RILA MOUNTAIN - BULGARIA)" -

published in the internationally renowned journal Ecological Engineering and Environment Protection (2018, No 2).

"SPATIAL DISTRIBUTION OF HIGH-MOUNTAIN ECOSYSTEMS - APPLICATION OF REMOTE SENSING AND GIS: A CASE STUDY IN SOUTH-WESTERN RILA MOUNTAINS (BULGARIA)" - published in the journal Silva Balcanica (2019, volume 20, number 3).

"Data Fusion for Ecosystem Services Assessment: a Case Study in Bulgarian South-western Rila Mountains" - this publication is in the process of being prepared for publication.

Thus, the total number of publications formed on the dissertation work is three - two already published in renowned international journals and one that is being prepared for publication. This shows a high level of scientific activity and the ability to independently develop original scientific results.

EVIDENCE OF THE ORIGINALITY AND INDEPENDENT DEVELOPMENT OF THE DISSERTATION

The developed dissertation thesis is the result of the author's independent scientific research activity, presented in an original manner through the application of an innovative methodological approach to assessing ecosystems in high-mountain regions and their response to climate change. The PhD candidate defines the object of the study for the purposes of the dissertation based on a literature review and interprets original concepts and methods for integrating data from various sources. The modern remote sensing methods acquired and applied by the doctoral candidate allow for a more precise tracking of the dynamics of highmountain ecosystems and the assessment of ecosystem services. For conducting the research, satellite images from various sensors (e.g., Landsat and Sentinel-2) were collected and analyzed, along with climate data processed using specialized GIS and statistical software. This approach allows for obtaining new results published in prestigious scientific journals. The dissertation has an interdisciplinary nature, which confirms the author's independent scientific initiative to contribute to the implementation of a complex and integrated model in environmental research.

LEVEL OF KNOWLEDGE OF THE STATE OF THE PROBLEM AND RELEVANCE OF THE LITERATURE USED

The dissertation demonstrates an in-depth understanding of the current state of the scientific problem, as the author references a rich and diverse body of literature—both international and national. This is evident from the cited sources in the publications, which refer to classical works as well as contemporary studies related to the assessment of ecosystem services and the impact of climate change on high-mountain systems.

The literature used in the dissertation integrates knowledge from ecology, climatology, and geoinformation technologies, reflecting modern trends and methodological requirements for solving complex ecological problems. The doctoral candidate demonstrates familiarity with the latest developments and standards in the field of ecosystem service assessment, utilizing

methodologies and models that have proven effective in analyzing natural systems in the context of global climate change.

The cited sources confirm that the selected methodology (including the calculation of NDVI, NDWI, NDGI, and the integration of climate data) is based on well-established scientific principles and practices. This contributes to the reliability of the study and the validity of the obtained scientific results. The dissertation shows a high level of understanding of the problem's state, with the selected literature being well-structured and aligned with the specifics of the research topic.

METHODOLOGICAL FRAMEWORK

The dissertation presents a well-founded and developed theoretical model that serves to integrate multiple data sources and methodological approaches in the assessment of ecosystems in high-mountain regions. A key characteristic of this model is the consideration of the ecosystem as a complex of interconnected structural and functional subsystems, encompassing biotic and abiotic heterogeneity, as well as energy, water, and material balances. This allows for tracking the dynamics of the ecosystem in the context of climate change.

The theoretical model integrates data from remote sensing observations (calculated indices such as NDVI, NDWI, NDGI), climate models, and field research data. Since the developed model is based on established scientific principles and approaches, its application serves as an adaptation of the National Methodological Framework for Mapping and Assessment of Ecosystems and Ecosystem Services they provide toward an integrated regional assessment. This provides a pilot basis for interpreting the results and formulating further studies and advancements. The model is dynamic and enables the tracking of temporal changes.

In summary, the selected methodology and research techniques are developed and adapted to meet the defined objectives and tasks of the dissertation. They provide an integrated approach for regional analysis of high-mountain ecosystems, monitoring climate change, and assessing the ecosystem services they provide, thus contributing to both scientific and practical significance in this pilot study.

CONFORMITY OF THE CHOSEN METHODOLOGY AND RESEARCH METHODOLOGY WITH THE SET GOAL AND OBJECTIVES OF THE DISSERTATION

The dissertation demonstrates a significant own contribution to the collection and analysis of empirical data, as well as some significant scientific, methodological and scientifically applied contributions achieved through the integrated analysis of climate and remote sensing data. They enrich theoretical models and provide practical tools for sustainable management of highmountain ecosystems. I consider the following to be more significant:

The dynamics of changes in the spatial distribution of the main ecosystem types and subtypes of ecosystems have been established, expressed in an increase and shift in altitude of forest ecosystems at the expense of grass and shrub ecosystems. According to the parameter forest canopy density, an increase in density up to 2,200 - 2,300 m a.s.l. has been observed.

The model for integrated assessment of ecosystem services has been piloted in a high-mountain region of the Rila National Park. New indicators have been formulated (e.g. for assessing changes in ecosystem coverage and ecological succession), which contribute to a more complex assessment of the ecosystem conditions. Adapting the parameters (e.g. for assessing the physical use of landscapes, cultural heritage and accessibility) to the specific conditions of high-mountain regions allows for a more accurate and applicable assessment of ecosystem services at the local level.

The developed methodology for integrated assessment of the functional condition of highmountain ecosystems through vegetation indices can be used in assessing vegetation cover in other combinations of terrestrial ecosystems and be applied in management plans for national and nature parks, forest enterprises, agricultural cooperatives, and other environmental management entities;

A set of measures is proposed to preserve and improve the potential of the studied ecosystems to provide cultural ecosystem services.

CRITICAL REMARKS AND RECOMMENDATIONS

Below are several critical remarks and recommendations that could improve the quality and applicability of the dissertation:

- Despite the extensive dataset used (satellite, climatic, and field data), there are periods with missing or insufficient detail, which limits the full temporal tracking of ecosystem dynamics.
- Differences in the resolution and characteristics of data from different satellite sensors (e.g., Landsat and Sentinel-2) may lead to inconsistencies in the calculated vegetation indices. It is recommended to introduce stricter procedures for cross-sensor calibration and data normalization.
- Some adapted parameters in the methodology (e.g., for assessing cultural ecosystem services) require further refinement and verification through expanded field studies to ensure their accuracy and reliability.
- The analysis of relationships between climatic parameters and vegetation indices could be expanded with a focus on local microclimatic characteristics, which significantly influence vegetation across different parts of the defined study area.
- To complement data from remote sources, it is important to increase both the number and quality of field measurements, as they contribute to a more precise scientific validation of satellite observations. At the same time, remote sensing methods provide sufficiently accurate and reliable data and are particularly valuable for rapid assessments of large or inaccessible areas.
- The current pilot study provides valuable experience in combining remote and fieldbased approaches, demonstrating their effectiveness and the potential for further methodological improvements.
- The consideration of additional indicators for ecosystem service assessment—especially in the context of cultural and regulatory ecosystem services—contributes to a more detailed and applicable analysis of ecosystem conditions. Given that this is a pilot study, it successfully demonstrates the application of specific indicators at the local level. However, a broader and more comprehensive evaluation of cultural ecosystem services could significantly enhance the methodological framework.

- Considering the continuous development of climate datasets (e.g., transition from ERAInterim to ERA-5), it is recommended to regularly update and calibrate the climatic models used to ensure compatibility with other data sources.

For the purposes of this dissertation, the author defines a "high-mountain ecosystem" in the southwestern parts of Rila National Park based on structural and functional criteria, highlighting its specific functional characteristics and spatial distribution. The author specifies that the "high-mountain ecosystem" under study represents a transitional zone between the mountain zone (dense forest area) and the subalpine (sparse forest) and alpine zones, and emphasizes that it consists of three main components—forest (including coniferous, broadleaf, and regrowth trees), grassland, and shrub ecosystems. Additionally, the text mentions that the area "also includes water bodies and sparsely vegetated lands".

Given the pilot nature of the study and its objective to apply an integrated assessment within a selected high-mountain area, I suggest using the more appropriate definition: "the highmountain region of Rila Mountain above 1,150 meters above sea level, including various ecosystem types". This definition better aligns with the English term "treeline ecosystem".

In summary, these critical remarks and recommendations aim to further refine the interpretative approach, enhance accuracy, and optimize the integration of various data sources, benefiting the doctoral candidate in future research.

CONCLUSION

The dissertation of the candidate Kostadin Katrandzhiev presents scientific, applied, and practical results, which provide an original contribution to the field of ecological research and meet the requirements of the Law on the Development of Academic Staff in the Republic of Bulgaria (ZDASRB) and the Regulations for the Application of ZDASRB at the Institute of Biodiversity and Ecosystem Research (IBER-BAS).

The submitted materials and achieved results are in accordance with the specifics of the research topic and the requirements of IBER-BAS. The dissertation demonstrates that Kostadin Katrandzhiev possesses the necessary theoretical knowledge and professional skills in the respective scientific field, as well as a proven ability to conduct independent, complex scientific research.

For the reasons stated above, I give my positive assessment of the conducted research, as presented in the reviewed materials, the dissertation abstract, the achieved results, and the scientific contributions.

I propose to the honorable scientific jury to award Kostadin Katrandzhiev the educational and scientific degree "Doctor" in the scientific field 4. Natural Sciences, Mathematics and Informatics, professional field 4.3. Biological Sciences, scientific specialty "Ecology and Ecosystem Protection".

26.02.2025

Reviewer:
Prof. Dr. Miglena Zhiyanski