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REVIEW

Reviewer: Assoc.Prof. Daniela Yordanova Avetisyan, PhD

Space Research and Technology Institute at the Bulgarian Academy of Sciences, appointed by Order No. 96/23.12.2024 of the Director of the Institute of Biodiversity and Ecosystem Research (IBER) at the BAS, Sofia.

Subject: Defense of a dissertation thesis for awarding an educational and scientific degree "Doctor" (PhD) in the area of higher education 4. Natural sciences, mathematics and informatics, professional field 4.3. Biological Sciences, Doctoral program "Ecology and Ecosystem Protection", at the Department of "Ecosystem Research, Environmental Risk Assessment and Conservation Biology" at IBER-BAS.

Author of the PhD thesis: Kostadin Marinov Katrandzhiev

Title: „Spatial analyses and high-mountain ecosystem condition and services assessment in Rila Mountains"

Scientific supervisor:: Assoc.Prof. Svetla Valeva Bratanova-Doncheva, PhD (IBER-BAS)

Scientific consultant:: Prof. Stoyan Nedkov, PhD (NIGGG- BAS) and Prof. Nesho Chipev, PhD (IBER-BAS)

General characteristics of the PhD thesis

The materials presented by Kostadin Marinov Katrandzhiev are in accordance with the Regulations on the conditions and procedure for acquiring scientific degrees and for holding academic positions at Institute of Biodiversity and Ecosystem Research (IBER) at the BAS and includes the following documents: list of documents for defense; title page of the PhD thesis; PhD thesis; abstract; reference for the scientific contributions of the PhD thesis; list of publications on the topic of the PhD thesis; attached copies of three published articles, together with a protocol for the distribution of scientific contributions between the co-authors of an article under item 6.1.1; list of participation in scientific forums with oral presentations and posters; list of citations of the scientific articles on the topic of the PhD thesis; scientific SV of Kostadin Marinov Katrandzhiev; Diploma for obtained master's degree of Kostadin Marinov Katrandzhiev; Diploma for obtained bachelor's degree of Kostadin Marinov Katrandzhiev; assessment of the preparation according to the credit system at the Bulgarian Academy of Sciences; summary of the PhD thesis in English.

The PhD thesis is 182 pages long, and it is structured according to the rules in 11 chapters, as follows: 1. Introduction; 2. Literature review; 3. Purpose of the PhD thesis; 4. Tasks; 5. Materials and Methods; 6. Results and Discussions; 7. Summary and Conclusions; 8. Contributions; 9. Acknowledgments; 10. References; 11. Copies of scientific articles on the topic of the PhD thesis, including:

Under item 6.1.1: Whole System Data Integration for Condition Assessments of Climate Change Impacts: An Example in High-Mountain Ecosystems in Rila (Bulgaria);

Under item 6.1.2: Application of Remote Sensing for High Mountain Ecosystem Condition Assessment (South West Rila Mountain - Bulgaria);

Under item 6.1.3: Spatial Distribution of High-Mountain Ecosystems – Application of Remote Sensing and GIS: A Case Study in South-Western Rila Mountains (Bulgaria);

Under item 6.1.4: Manuscript of a potential scientific article with a working title: Data Fusion for Ecosystem Services Assessment: a Case Study in Bulgarian South-Western Rila Mountains.

The list of references includes 70 titles, of which 68 are in English and 2 in Bulgarian. The PhD thesis contains: 17 figures in the main body of the PhD thesis, 12 figures in the attached article under item 6.1.1, 6 figures in the attached article under item 6.1.2, 9 figures in the attached article under item 6.1.3 and 6 figures in item 6.1.4, as well as 5 tables in the main body, 3 tables in the attached article under item 6.1.1, 2 tables in the attached article under item 6.1.2, 2 tables in the attached article under item 6.1.3 and 1 table in the attached article under item 6.1.4. In total, this makes 50 figures and 13 tables in the PhD thesis.

The purpose of the dissertation "Critical analysis and assessment of the functional state of a defined highland ecosystem in the South-Western parts of the Rila National Park, as well as assessment of its capacity to provide selected ecosystem services (ES), with the application of remote sensing methods and GIS" is clearly formulated. The tasks set for its implementation are correctly presented and justified.

General presentation of the candidate

Kostadin Katrandzhiev graduated with a Bachelor's degree in “Ecology” from the New Bulgarian University in Sofia in 2010. He received his Master's degree from the same university in “ Environmental Management” in 2012. From 01.01.2016 to 31.12.2018, he was a full-time PhD student in the Ecosystem Research division at the Institute of Biodiversity and Ecosystem Research (IBER) at the BAS, Sofia. After completing his PhD studies (31.12.2018), he was dismissed with the right to defend a PhD thesis on the topic: "Spatial analysis and assessment of the state and ecosystem services of ecosystems in the upper forest boundary of Rila" - a form of presentation - bound articles. He participated in the "National Program for Young Scientists and Post-Doctoral Students" with a project on the topic "Remote sensing for assessment of high-mountain ecosystems in Southwestern Rila under conditions of climate change" in the period April 2019

- December 2021. He underwent specialized training related to processing, analysis, and interpretation of satellite data at the SRTI-BAS and under the supervision of Prof. Rumen Nedkov between April 2019 and January 2020. He has participated in conferences, workshops, seminars, and training in ecology. He has five scientific publications. He is the lead author in three of them. He has participated in ten projects, half of which are international.

Literary awareness and theoretical preparation of the candidate

The PhD candidate shows good awareness of the research related to the PhD work. This is confirmed by the presented bibliography in the PhD thesis and the attached publications. The chapter dedicated to the literature review is divided into four main parts, examining in detail the theoretical basis for the concept of a high mountain ecosystem and structural characteristics; High mountain ecosystems and climate change - connections and structural challenges; High mountain ecosystems - the role of remote sensing methods in the assessment of their state; High mountain ecosystems and their services: Remote sensing methods in their evaluation. For the concept of "High Mountain Ecosystem" (HME) and its characterization, the PhD student has chosen to use the terms "upper forest border" and "ecotone", citing various sources applying this approach. Various aspects of studying the influence of climate change on the composition and functions of HME have been examined. Significant attention is paid to monitoring the response of HME to past and future climate changes. This aspect is fundamentally embedded in the development of the PhD thesis and the literature references include over 10 sources. The complexity of the interactions between the individual components in the composition of HME under the influence of climate change and the challenges faced by the scientific community in their assessment is considered an important issue. The PhD student introduced the role of remote sensing methods in addressing the identified challenges. It is emphasized that "To meet the challenges of developing methods and tools for assessing the condition and services provided by HME, the science is developing towards complementing field methods with remote sensing methods". This approach allows for an increase in the scale of research, which consists of upscaling from the "individual" level to the "ecosystem" level. Attention is paid to the mapping of ecosystems and their services, which in Bulgaria takes place in the period from 2010 to 2017. Vegetation indices, widely used in remote sensing methods, are presented in detail. Some of their main applications are listed, supported by examples and theoretical justification. Attention is paid to the search for a balance in the demand and supply of ecosystem services and the aspect of the high vulnerability of HME when this balance is disturbed. In the context of technological advances in remote sensing, specific examples are discussed to demonstrate their applicability in studying more detailed aspects of the natural environment. The increase in the number of studies focusing

on ecosystem services with the use of RS methods has been noted. It emphasized the importance of performing field studies to increase the accuracy of assessments based on remote sensing methods.

Methodological approach

The materials and methodological approach are presented in detail in three sections, describing: the object of research; the data and data processing; and the methods used.

An adapted version of the Methodological Framework for Assessment and Mapping of the State of Ecosystems and Ecosystem Services in Bulgaria, concerning the Methodologies for Assessment and Mapping of the State of Forest, Grassland and Shrub and Ericoid Ecosystems and their Ecosystem Services (ES) was used. Due to the heterogeneity of the research object and limitations related to the data, the "Whole System" approach was applied. This approach considers the selected HME as a set of functionally related components, organized into two categories - structural and functional. This is a dynamic approach, allowing the use of data time series on the balances of energy, matter and water by the application of vegetation indices and integration of climate models. Another advantage of the "Whole System" approach is that it allows for the provision of ecologically sound indicators that contribute to environmental accounting and, in particular, to assessments related to the extent and condition of ecosystems.

The methodology also includes criteria for the selection and assessment of 3 cultural ecosystem services, given the presence of a cultural monument on the territory of the studied High Mountain Ecosystem (Radonov Grob).

I evaluate the methodology used as adequate and effective for the objectives and nature of the work. To achieve the goals of the PhD thesis, the methodology successfully integrates different types of data and complements the Methodological Framework for Assessment and Mapping of the State of Ecosystems by introducing the "Whole System" approach.

Significance and credibility of the obtained results, interpretations and conclusions

Analysis of the obtained results is presented in the main body of the PhD thesis, as well as, in the four attached articles, where they can be examined in a greater detail. Three of the articles have been published and have accordingly undergone scientific peer review, and one of them is in the form of manuscript.

According to the proposed methodology, three main components in the composition of the High Mountain Ecosystem have been identified as structures - forest, shrub, and grassland. Water bodies and sparsely vegetated components are involved also in the HME structure formation. The forests are divided into three sub-components – conifer, broadleaves, and coppice forests. Changes in the extent of the studied HME are identified. An increase in the density of the coniferous and deciduous subsystem components

towards the subalpine and alpine zones of the HME for the period from 2003 to 2018 is observed. Changes in the structures of the grasslands are also observed. In terms of the functional characteristics, it has been established that during all growing seasons of the 42-year study period, the HME functioned without indications of stress or disruption of the ecosystem integrity. These observations are valid also during accelerated changes in the climatic parameters of the environment, showing that the studied HME demonstrates long-term functional resilience to climate change. The results obtained show that the methodological approach used is adaptable and well-applicable for processing, fusing, and statistical analysis of heterogeneous data and their general interpretation. The applied "Whole System" approach is adequate and reliable for the development of parameters and indicators in the assessment of the selected ecosystem services. It has been developed in a way that allows its use at different levels (national, regional, local) and for different purposes, which distinguishes its practical importance. The approach also has its scientific significance, expressed in the development of a set of recommended measures, the implementation of which has the potential to improve the results of future studies, which could be included in the development of management plans. I consider that the presented results, interpretations and conclusions are logical and prove the achievement of the set goal of the dissertation. The obtained results are convincing and are distinguished by practical and scientific significance.

Critical notes to the PhD thesis

The PhD thesis is presented according to the regulations of the Institute of Biodiversity and Ecosystem Research (IBER-BAS), allowing the form of presentation through bound articles. This manner of presentation, although not belittling the contributions of the PhD thesis, makes its perception, structuring, and readability more difficult. This manner of presentation, although it does not underestimate the contributions of the dissertation, makes its perception, structuring, and readability difficult.

It is difficult to distinguish the volume of the presented chapters, which is especially important regarding the presentation of the methodology used and results. This hinders the assessment of the volume and balance of the presented chapters in particular and of the PhD thesis in general.

Lists of figures, tables, and abbreviations are missing. It is worth noting that some of the figures presented in the main body of the PhD thesis and the attached publications are of similar content, which makes it difficult to estimate their number. The references are not numbered either.

The presentation through bound articles has led to bilingualism of the text of the dissertation, without the content of the multilingual texts being identical. As a result, in the main body the text is in Bulgarian, but there are figures with legends in English, obviously borrowed from publications presented in English. Geographical coordinates and scale are missing in most of the maps.

As a shortcoming regarding the candidate's literary awareness and theoretical preparation, I would point out the insufficient presentation of contemporary research in the research area and the need for a more in-depth study of research at the regional and local level, given the specificity of the topic. It is noticeable that less than 10% of the literature used in Chapter 2. *A literature review* is from the last 5 years. The share of publications with a study area in Bulgaria is similar, although there are hundreds of articles from our country, including from recent years.

Nature of scientific contributions

As a result of the research conducted, the generalizations and conclusions made, the PhD candidate formulated 9 main contributions, differentiated into 3 groups: scientific, methodological and scientific-applied.

I accept the reference of the scientific contributions in the dissertation, considering that 6 of them are distinguished by originality (all falling into the "methodological" group, one from the "scientific" group and one from the "scientific-applied" group), but the remaining 3 are of a confirmatory nature.

In my opinion, the greatest importance has the scientific contribution, which highlights the sustainability and functional stability of the studied HME over a period of 42 years. Of the methodological contributions, the first two listed are distinguished with a greater significance: 1) Geospatial identification of the forest component in the composition of HME up to level 4; and 2) Development of two potential indicators to complement the Methodological Framework.

I rate the specified scientific-applied contribution to a developed methodology for assessing the functional state of HME through vegetation indices as "confirmatory". I justify this assessment with the argument stated in my critical notes about the PhD candidate's literary awareness, namely that there are hundreds of examples from our country, including from recent years, which use vegetation indices to assess the dynamics of different types of vegetation cover and ecosystems, including assessments of the ecosystem services they provide.

In this regard and with the same argument, I also evaluate as "confirmatory" the scientific contribution that establishes the dynamics of change in the spatial distribution of the main types and subtypes of ecosystems, expressed in the increase and displacement of forest ecosystems in height, at the expense of grass and shrub ecosystems. Such a pattern has been established by other authors for other HMEs in the country. The establishment of a statistically significant increase in temperature is also of a “confirmatory” nature.

Evaluation of the quality of the scientific publications reflecting the studies in the PhD thesis

Kostadin Katrandzhiev presents three published articles as part of his PhD thesis and one prepared manuscript. In all of the attached publications, the PhD candidate is the lead author, and in one of them, he is the sole author. The two joint articles have been published in scientific journals indexed in WoS and/or Scopus and fall in quartiles Q1 (“Diversity”) and Q4 (“Silva Balcanica”), respectively. The individual article was published in “Ecological Engineering and Environment Protection”, a journal not indexed in WoS, Scopus, ERIH+, or other profiled databases, thematic collections, incl. proceedings of international and national scientific forums., With the presented publications, Kostadin Katrandzhiev covers the current national requirements, the requirements of the Bulgarian Academy of Sciences, and of IBER-BAS for acquiring the educational and scientific degree of "doctor" (PhD). Part of the PhD thesis results have been included in two oral and three poster presentations, presented at international and national scientific forums. A list of citations for them is attached - 5 in total.

Reasoned answer to the question to what extent the research in the PhD thesis is primarily the personal work of the PhD candidate

In my opinion, Kostadin Katrandzhiev's personal participation in the preparation of the PhD thesis is undeniable. This opinion of mine is supported by the fact that in all the attached articles, on the subject of the PhD thesis, he is either the first or the only author.

The scientific leadership of its scientific supervisor - Assoc. Prof. Svetla Bratanova-Doncheva, as well as the scientific consultants - Prof. Stoyan Nedkov and Prof. Nesho Chipev, must be taken into account. Their involvement in the PhD thesis preparation is a guarantee for the quality of the research conducted. The acquired theoretical and practical skills in the processing and analysis of satellite data and their integrated use with other types of data in the preparation of statistical analyses, acquired under the guidance of Prof. Roumen Nedkov at the SRTI-BAS, should not be overlooked either. For me, Prof. Roumen Nedkov's commitment to Kostadin Katrandzhiev's training is also a guarantee of quality and evidence of his personal participation in the preparation of the PhD thesis.

Summary of the PhD thesis with English abstract

The submitted abstract includes 26 pages with attached basic graphic material, fully and correctly reflecting the essence of the PhD thesis. The formulated contributions and publications on the topic correspond to those listed in the dissertation. The publications on the dissertation are presented with a reference to their citations, as well as the participation of the PhD candidate in scientific forums. The abstract fully meets the requirements of the Law.

Reasoned conclusion

The dissertation and the presented materials contain scientific, methodological, and scientific-applied results that represent an original contribution to science and meet all the requirements of the Law on the Development of the Academic Staff in the Republic of Bulgaria (ZRASRB), the Regulations for the Implementation of the ZRASRB and the specific requirements of the Terms and Conditions and the procedure for acquiring scientific degrees and holding academic positions at the Institute of Biodiversity and Ecosystem Research at the Bulgarian Academy of Sciences, Sofia. The PhD thesis shows that the PhD candidate Kostadin Marinov Katrandzhiev possesses in-depth theoretical knowledge and professional skills in the scientific specialty “Ecology and Ecosystem Protection", demonstrating qualities and skills for independently conducting scientific research. For this reason, I propose to the honorable scientific jury to award the educational and scientific degree "doctor" (PhD) to Kostadin Marinov Katranjiev in the area of higher education: 4. Natural sciences, mathematics, and informatics, professional field 4.3. Biological Sciences; Doctoral program "Ecology and Ecosystem Protection".

18/03/2025
Sofia

Reviewer:
(Assoc.Prof. Daniela Avetisyan, PhD)