Prof. dr hab. Oimahmad Rahmonov
Faculty of Natural Sciences
Institute of Earth Sciences
University of Silesia in Katowice
41-200 Sosnowiec
e-mail: oimahmad.rahmonov@us.edu.pl

Sosnowiec, 25.04.2025

REVIEW

doctoral thesis by Mr. Umberto Grande entitled "Goal functions and assessment of natural capital and ecosystem services", carried out at the Department of Geobotany and Landscape Planning, Nicolaus Copernicus University in Toruń Faculty of Biological and Veterinary Sciences in cooperation with the UNESCO Chair "Environment, Resources and Sustainable Development", Parthenope University of Naples, Italy, Supervisors: DSc Agnieszka Piernik, prof. NCU, prof. Pier Paolo Franzese, prof. (ass) Elvira Buonocore

The doctoral dissertation covers the issues of broadly understood ecosystem services and methods of their valuation, especially in the area of natural capital, ecological complexity and ecosystem efficiency in diverse environmental conditions. There are many methods for valuing ecosystem services (economic and biophysical approaches), depending on the goal and valuation of the selected ecosystem element. In ecological studies and the study and functioning of biocenotic systems, the best approach is the biophysical approach. This approach was used following the goal of the work, which was to use the biophysical approach to study the exchange of matter and energy flows in the functioning of ecosystems, with particular emphasis on the assessment of natural capital and ecosystem services. The aim is to assess the intrinsic value of natural systems, enabling a comprehensive understanding of their complex dynamics through Goal Functions (GF), which can be used to characterise the state and functional and structural characteristics of an ecosystem, describing the tendencies of an ecosystem to move toward a specific state, often associated with increased stability, complexity, or energy flow efficiency. For this reason, I believe that the choice of this (biophysical) approach to the valuation of ecosystem services and natural capital in the discussed issue is justified and proper.

Structure of the dissertation

The doctoral dissertation submitted for review by Mr. Umberto Grande consists of four parts. The first part includes an introduction, which contains a concise, detailed review of the literature on both the analysed problem and the ecological services themselves (their

categorisation, valuation), with special attention paid here to works that used the biophysical approach in the valuation of ecosystem services. The advantages and disadvantages of the economic and biophysical approaches regarding ecosystem service valuation are presented. This part presents the objectives of the work and the research hypotheses. The goals are clear and understandable and concern the application of a biophysical approach to the study of matter exchange and energy flows in the functioning of ecosystems, taking into account the assessment of natural capital and ecosystem services. Three hypotheses were put forward: lakes of different trophic levels, i.e. oligotrophic, mesotrophic and eutrophic, differ in terms of the value of natural capital, system complexity and functioning using the emergy and eco-exergy functions (1), natural capital resources can be influenced by environmental parameters and anthropogenic pressures, and their changes can be detected using thermodynamic goal functions (2), and the variability of the supply of ecosystem services can be caused not only by human activity but also by intense natural disasters (3). Each hypothesis was tested, and the results were presented in the form of an article (1) and manuscripts (2) submitted to the journal as Mr. Grande's doctoral dissertation.

The second part is about methods, in which the author briefly explains the concept of emergy and its application in environmental sciences. He also presents a step-by-step emergy accounting scheme for the analysis of ecosystem resources. In a similar framework as emergy, Eco-exergy, Shannon diversity index and the System of Environmental Economic Accounting-Ecosystem Accounting (SEEA-EA) framework for ecosystem asset accounts are explained. Also here ("Data sources and methodological applications") the PhD student presents the characteristics of the analysed lakes (Czarne, Zmarle and Laska) in terms of the degree of development, trophy, "mixing", area, depth and driving factors of lake ecosystems. *Some of the information presented here can be found in the published article, may have been omitted, or is a repetition of information* (it could have been avoided). The repetition concerns the Methods chapter and its subchapters, I believe that they should not be described in detail here, especially since such information is found in the presented article and the submitted manuscripts.

In the case of emergy analysis, environmental data such as solar radiation, rain, wind, geothermal flow, nitrogen and phosphorus were taken into account for each lake, and the analysis was based on literature and local data. The methods for their calculation were presented clearly and convincingly and are useful for other researchers in the future.

In this thesis (in the case of the marine ecosystem), an eco-exergy assessment based on the Mediterranean International Trawl Survey (MEDITS) dataset was conducted to determine the population of demersal fishes in NC (natural capital) from 2005 to 2021. Following the MEDITS protocol, the survey was conducted during the spring season. The number of samples collected is adequate for this type of study. Considerable amounts of data were collected from the Copernicus Marine Environment Monitoring Service and others, demonstrating the PhD student's ability and skills to use publicly available data in scientific work. In turn, the assessment of the range of forest ecosystems was carried out using GIS software to classify land cover (in the case of Tuchola Forest). Materials and methods are presented clearly and in detail; where data from the literature (or Internet sources) were used, the sources were always cited.

The third part includes research results, which includes one published publication and two manuscripts in the review stage. These articles, thematically related and constituting a coherent whole, are:

1. Grande U., Piernik A., Nienartowicz A., Buonocore E., Franzese P. 2023: Measuring natural capital value and ecological complexity of lake ecosystems, Ecological Modelling, vol. 482, 110401, p. 1-9, DOI:10.1016/j.ecolmodel.2023.110401, IF(2,6), MNiSW: 100,

2. Grande U., Buonocore E., Fiorentino F., Franzese P.P, Lauria V., Piernik A., Sabatella E., Scannella D, S. Vitale S., G. Garofalo G. Applying goal functions for natural capital stock change assessments in marine ecosystems. Conservation Biology (planned submission awaiting coauthors' approval)

3. Grande U., Husein K., Nardella L., Kamiński D., Buonocore E., Franzese P.P., Piernik A. Assessing forest ecosystem assets and services based on an international statistical standard. Ecological Indicators (under review)

The published article and manuscripts submitted for evaluation are co-authored. Mr. U. Grande is listed as the first author in all of them and as the corresponding author in one paper (in the third manuscript, the corresponding author was not specified). The dissertation does not include a statement detailing each author's contribution to the respective publications or manuscripts. Therefore, it is difficult to fully assess the doctoral student's individual input. However, given that he is the first author in all the submitted materials, his role can reasonably be considered primary.

Topics of articles

Article 1 (title: *Measuring natural capital value and ecological complexity of lake ecosystems*) – has passed the peer-review process and meets the high requirements for reputable journals (indexed in the Web of Science, Scopus databases) in terms of content, language and editing, and in my opinion represents a high scientific level. The article consists of seven figures, eight tables, 63 references and nine citations.

In this article, the authors analysed natural capital values and ecological complexity of lake ecosystems in the UNESCO-MAB Tuchola Forest Biosphere Reserve. These changes were studied using different ecological goal functions such as emergy and eco-exergy. These functions were applied to assess the exchange of matter and energy flows in the analysed lake ecosystems representing different trophic levels (oligotrophic, mesotrophic and eutrophic) - serving as methods for evaluating ecosystem performance through emergy and eco-exergy accounting. In particular, emergy was used to account for the work of nature invested in generating natural capital stocks, while eco-exergy was used to characterise the stage of development of lake ecosystems, reflecting their trophic and health state. The results showed that the eutrophic lake showed both the highest investment of emergy in generating natural capital stocks and the highest value of eco-exergy density. In turn, the eco-exergy method allowed for the assessment of the state of development, information content and complexity of the three studied lakes. Based on the conducted research, the authors calculated the eco-exergy/emergy ratio to determine the efficiency of the studied lake ecosystems. The results obtained by the authors were consistent with the different trophism of the studied lakes, confirming how external driving forces can direct the development and complexity of lake ecosystems. As the authors emphasise, integrated assessments adopting an ecosystem and holistic perspective may prove to be a promising approach to studying lake ecosystems in different ecoregions of the world, providing information to decision-makers involved in ensuring sustainable management of surface water ecosystems. I only have one comment: this work lacks basic information on physical and geographical elements, such as terrain and wind directions. Instead of a satellite image, a simplified scheme of vegetation distribution in relation to the studied lakes could be included as a part of Fig. 1. This is a very interesting and valuable work; the results are well-documented in the form of graphs and tables, and the detailed, step-by-step description of the methodology makes the approach easily replicable by other researchers.

Manuscript 1 (title: *Applying goal functions for natural capital stock change assessments in marine ecosystems*) - its status at the dissertation is as planned submission awaiting coauthors' approval, in Conservation Biology (IF:5,2, MNiSW: 140). The study covered the spectrum of temporal and spatial determination of natural capital changes under the influence of environmental and anthropogenic factors, using thermodynamic objective functions to assess NC changes in marine ecosystems. Thanks to this function, the changes in the natural capital of demersal fish resources were determined under the influence of environmental parameters (Sea-Surface Temperature-SST; Sea-Surface Salinity-SSS, seawater pH, and net primary production-PP) and anthropogenic pressure. For this purpose, the marine ecosystems of the Mediterranean Sea affected by human activity (Strait of Sicily, Italy) were studied. Therefore, the main aim of this study was to assess changes in the natural capital of demersal fish resources. To assess the dynamic of natural capital and ecosystem complexity (from 2005 to 2021), the eco-exergy and Shannon diversity index were used. It is worth paying attention to the detailed description of the methodology and data analysis, which will help the reader understand the essence of the obtained results.

The results section presents the average relative contribution of taxonomic groups to the eco-exergy value of natural capital, where it is clearly indicated that bony fishes contribute the largest amount to the total eco-exergy, ranging from 62% to 74%. This is important information in the context of the ecosystem provisioning service. The research results in the field of natural capital and stock changes have been thoroughly developed and checked using statistical methods and do not raise any doubts.

Among the environmental factors affecting changes in natural capital, anomaly trends were identified for selected environmental variables from 2000 to 2021. It was found that all variables, except PP, showed a consistent pattern, with a constant change in anomaly signs between 2011 and 2012. In particular, SST and SSS recorded above-average values after 2011, while pH showed consistently below-average values from 2012 onwards. On the other hand, PP did not show a constant change in anomaly signs. The authors found a significant positive correlation between Eco-exergy and environmental parameters (pH, PP) and fishing effort, while a negative correlation was found with SST. This paper has an applied nature (application character), and its results can provide meaningful and helpful information to decision-makers that will support strategic environmental actions and effective and sustainable fisheries management in the broader context of maritime spatial planning. Based

on the results presented, it is possible to draw more detailed conclusions than those currently presented in general terms in the article.

Manuscript 2 (title: *Assessing forest ecosystem assets and services based on an international statistical standard*) has been submitted to Ecological Indicators: IF-7.0, MNiSW: 200 (under review). This manuscript aims to implement the SEA-EA (Environmental Economic Accounting-Ecosystem Accounting) framework in the MAB Biosphere Reserve (Tuchola Forest) by assessing the variability of ES supply caused by natural disasters. This article is very interesting both in the context of the naturalness of the research object and the natural event that affected the functioning of this object. Hence, the comparison of ecosystem services before and after the hurricane indicates the potential of forest ecosystems (deciduous and coniferous forests) in climate regulation and air purification. Below I present its strengths and weaknesses. The weaknesses of the manuscript mainly concern the organisation, order and supplementation of the article in the event of its further processing.

Strengths

1. I appreciate the prepared workflow, such visual representations are always valuable—often more so than a purely verbal description of the methodology. However, it appears that the CLC spatial data from 2018 is not used. Is this an error, an oversight, or an intentional decision? As in the case of the pollution data, the year 2018 is mentioned in both cases.
2. The detailed description of the equations and monetary conversions used is clear, concise, and specific, making it easy to understand. This part could effectively serve as the starting point for the methodology section.
3. The results are presented in a very legible, accurate and clear manner. The findings are both important and scientifically interesting.
4. The discussion about the impact of air pollution on human health is particulary strong. This aspect could be further emphasised because it is not even about general well-being (also understood as mental health) but more directly in terms of its effectson physical health.

Weaknesses

1. The title of the manuscript is very general, it does not provide a specific valuation of the ecosystem services category or area. The work in this context concerns only the category of regulating services, the title is misleading.

2. The description of the methodology shows that the Authors focus only on ecosystem services (regulation) related to air purification by forests. This should be clearly and distinctly evident from the title of the article, abstract and introduction, where the purpose of the work is stated. The current title and abstract wrongly lead the reader to believe that the work concerns all ecosystem services, and not just one of the groups (i.e. ecosystem services already at the third degree of precision) - this significantly narrows the tone of the work.

3. On the map Figure 1. It is worth marking the names of towns or other geographical names for a better location of the studied area. The current map without them is "empty" and incomplete. In addition, some names on the map are blurred, which indicates poor graphic resolution. Separating the boundaries of deciduous and coniferous forests based on phototones was also possible.

4. The description of the methodology is mixed with the description of the materials used for the individual stages of the work. Stylistically, it is overly verbose and contrasts with the short, specific, well-written introduction. If the article is rejected by *Ecological Indicators*, this section should be rewritten to eliminate unnecessary repetition and to clearly separate the methodology from the detailed description of the materials used.

5. Map Figure 3 is of poor resolution – the forest polygons and the inscriptions on the map are blurred. As in the previous map, you can overlay geographical names (at least a few) for better spatial localisation. Figure 4-7. Resolution needs to be improved.

6. The conclusions are written very generally (Its concern also second manuscript). I suggest emphasising specific findings from the research more, e.g. in the form of bullet points. Something like highlights so that the conclusions clearly show what was proven in the research.

7. The authors use the phrases "must be selected" - this is too strong a definition, it is better to write that according to the SEEA-EA methodology it is selected. Please also avoid writing in the first person plural or singular ("we", "I").

8. There is no alphabetical order in the references.

A question I would like to have answered during the public defense

1. In the methodology section, the authors state that the spatial resolution was set at 10 m, which is appropriate for the CLC from 2018, whose resolution is defined as 10-15 m. However, this resolution is not suitable for the CLC from 2012, which, according to the Copernicus Land Monitoring Service, has an accuracy of 25 m. This suggests that the authors

artificially doubled the spatial resolution for this dataset, despite the data quality only supporting a 25 m resolution. This is a common mistake among CLC users: although the dataset is valuable resource, it has significant limitations that are often overlooked. Please explain this methodological choice.

2. Is the selection of only four air pollution indicators sufficient? The author consider PM10, PM2.5, ozone and nitrogen dioxide as pollution indicators. However, several other important air quality parameters are omitted, such as greenhouse gases, carbon dioxide, sulfur oxides and others. Can such a complex issue as air-related ecosystem services truly be assessed based on just four indicators? Especially considering that air quality is also influenced by numerous other factors, including meteorological variables (temperature, wind, pressure systems), the number and types of emission sources, and the aforementioned additional pollutants.

3. I disagree with the first sentence of the discussion, which claims that the study provides a comprehensive overview of SEE-EA. Due to the limitations mentioned above, the study cannot be considered comprehensive. It focuses only on a single category of ecosystem services, uses just four air quality indicators, and limits the analysis to forests. Please provide justification for this claim and convince me otherwise.

Conclusion

The published (1) and submitted manuscripts (2) generally present assessments and valuations of ecosystem services (partly within the categories of provisioning and regulation) across different ecosystems, using a multi-method approach. The materials presented by the PhD student (both publications and manuscripts) are structured in a well-considered, logical sequences with high scientific merit. The presented critical remarks and comments do not affect the overall positive evaluation of the dissertation.

The dissertation reflects Mr. Umberto's strong theoretical knowledge and solid research experience. The doctoral student has fully tested the research hypotheses and achieved the objectives set out in the dissertation. He collected relevant data and materials, analysed them thoroughly, and incorporated them in the planned series of articles (one published, two submitted), which, together with the accompanying commentary, fulfil the requirements of a doctoral dissertation. All results were subjected to statistical analysis. The doctoral student has demonstrated the ability to formulate scientific problems, a sound knowledge of the relevant literature, and the ability to draw accurate and well-founded conclusions.

In conclusion, I state that the doctoral thesis of Mr. Umberto Grande entitled: ***„Goal functions and assessment of natural capital and ecosystem services"*** meets the requirements outlined for postgraduate dissertations in Article 187 of the Act of 20 July 2018 - The Law on Higher Education and Science (consolidated text Journal of Laws of 2023, item 742). Therefore, I respectfully request the Disciplinary Council of Biological Sciences at Nicolaus Copernicus University in Toruń to allow Mr. Umberto Grande to proceed to the following stages of the doctoral process.