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dr hab. Tomasz Szymura prof. UWr

Botanical Garden

tomasz.szymura@uwr.edu.pl

Review of the Doctoral Dissertation of MSc **Umberto Grande** entitled ‘**Goal Functions and the Assessment of Natural Capital and Ecosystem Services**’.

This review was conducted in accordance with a decision made by the Disciplinary Council of Biological Sciences at Nicolaus Copernicus University in Toruń on March 28, 2025. The dissertation was completed in the Department of Geobotany and Landscape Planning at Nicolaus Copernicus University in collaboration with the UNESCO Chair on "Environment, Resources, and Sustainable Development" at Parthenope University of Naples, Italy. It was supervised by Dr. hab. **Agnieszka Piernik**, prof. NCU; Prof. **Pier Paolo Franzese**; and Prof. (ass) **Elvira Buonocore**.

The dissertation consists of 119 pages and is divided into six chapters. The most extensive and crucial chapter, "Results" (Chapter 3), includes one published scientific article, one manuscript submitted for publication, and one text prepared for submission that is awaiting the consent of co-authors before being sent to a scientific journal. The submitted works are as follows:



1. Grande, U., Piernik, A., Nienartowicz, A., Buonocore, E., & Franzese, P. P. (2023). *"Measuring Natural Capital Value and Ecological Complexity of Lake Ecosystems."* *Ecological Modelling*, 482, 110401.

2. Grande, U., Buonocore, E., Fiorentino, F., Franzese, P. P., Lauria, V., Piernik, A., Sabatella, E., Scannella, D., Vitale, S., & Garofalo, G. *"Applying Goal Functions for Natural Capital Stock Change Assessments in Marine Ecosystems."* (Submission planned in 'Conservation Biology', currently awaiting co-authors' approval).

3. Grande, U., Husein, K., Nardella, L., Kaminski, D., Buonocore, E., Franzese, P. P., & Piernik, A. *"Assessing Forest Ecosystem Assets and Services Based on an International Statistical Standard"* (under review in **Ecological Indicators**).

In all submissions, MSc **Umberto Grande** is the first author, and in publication no. 3, he is also the corresponding author. His contributions to publications 1 and 2 included research, data curation, software operating, interpretation of results, and writing. In publication no. 3, while Grande's specific involvement is not detailed, he is the first and corresponding author.

All manuscripts focus on the concept of natural resources as capital that provides ecosystem services. The dissertation features three case studies from distinct ecosystems: lakes in a temperate climate (1), the Mediterranean Sea (2), and temperate forests (3). Three hypotheses were tested in the dissertation:

1. Lakes of differing trophic levels, namely oligotrophic, mesotrophic, and eutrophic, differ in terms of natural capital value, system complexity, and function.

2. Natural capital complexity can be influenced by human activity and environmental factors, leading to changes over time.

3. Variation in ecosystem service supply can result from both human activities and significant natural disasters.

The overall layout of the dissertation is appropriate, generally easy to follow, and facilitates the review. The individual articles follow the conventional structure of scientific articles, including sections for Introduction, Materials and Methods, Results, and Discussion.

The questions addressed in the dissertation are relevant and significant for sustainable development and nature conservation. Notably, the novelty claimed consists of the combined use of emergy and eco-exergy methods to evaluate the biotic components and natural capital stock of ecosystems, which the authors propose as a benchmark for future comparisons, appealing to an international audience. The second article offers a new assessment for a specific region, the Strait of Sicily (Mediterranean Sea), while the third represents the first implementation of the SEEA-AE framework for the MAB Biosphere Reserve, assessing changes in ecosystem services caused by natural disturbances. The hypotheses investigated are intriguing for scientists focused on ecological modelling related to natural capital, and the testing was conducted with rigorous scientific methodology. Therefore, my overall evaluation of the dissertation is positive.

Despite this positive assessment, I do have some concerns regarding the titles of the submissions. For instance, the title of submission 3, ‘Assessing Forest Ecosystem Assets and Services Based on an International Statistical Standard’, led me to anticipate a broader range of assessed ecosystem services than the four aspects of air pollution removal that were actually analyzed. A similar concern applies to publication 1, ‘Measuring Natural Capital Value and Ecological Complexity of Lake Ecosystems’. The merit of my concerns lies in the fact that significant issues relevant to broader audiences, such as the valuation of ecosystem services, the relationship between ecosystem services and disservices, and the connection between biodiversity and ecosystem services, often depend on the variety of services evaluated.

I also have some additional doubts regarding article no 1 (Measuring Natural Capital Value and Ecological Complexity of Lake Ecosystems): How the indices calculated for the lakes will change seasonally? I assume that the biomass of macrophytes, algae, and birds will change substantially over seasons, so what indices represent: the functioning of the ecosystem in a biomass productivity peak, and are the peaks correlated for different trophic groups? I have also some questions on this topic: the fundamental article of Jørgensen et al (2005) which quantifies the beta coefficient was published in 2005 (*Jørgensen, S. E., Ladegaard, N., Debeljak, M., & Marques, J. C. (2005). Calculations of exergy for organisms. Ecological Modelling, 185(2-4), 165-175*). As Jørgensen (2005) et al. wrote ‘*It is clear that we do not have the knowledge that is needed to find the correct β -values for calculation of an exergy index (or we may call it, the index for the distance to the thermodynamic equilibrium) for an ecosystem model*’ and ‘*The present list (Table 4) must, however, be permanently updated, as more certain measures of the information embodied in the organisms and about the complete genome size become available*’. It has been about 19, very prolific, years since the words were written. How look like the development in the calculation of the β -values?

I also have some doubts regarding the approach used in submission 3 (‘Assessing Forest Ecosystem Assets and Services Based on an International Statistical Standard’). First, use of the terms ‘*hurricane destroyed (...) forests*’ and ‘*natural disasters such as hurricanes*’. Recently the strong winds are considered as a typical type of disturbance for which forest ecosystems are adapted, moreover from an ecological, not a forester, point of view the hurricane destroys the stands of mature trees, but not the entire forest ecosystems. Additionally, the approach used is correct and logical, but it seems to me a little bit oversimplified (or even naïve): since air pollution removal is a function of the NDVI index, which in turn, emerges from chlorophyll volume, it is clear that decrease of living canopy volume will decrease the air pollution removal ability, in case of forest ecosystems. Similarly, since the nitrogen dioxide and ozone uptake is a



function of forest area, the forest area decrease (defined following the CORINE typology) caused a decrease in pollutants uptake. Nonetheless, it will be interesting to assess the uptake made by the transitional woodland shrubs class, which in CORINE typology represents vegetation on clear-cuts and areas under forest succession. By the way how the spatial accuracy of CORINE was set at 10 m, while its minimum mapping unit of the original data is 25 ha or 100 m in the case of linear objects (<https://land.copernicus.eu/en/products/corine-land-cover>)? Moreover, it is not clear to me what values of stomatal conductance were used in the modelling, especially since the conductance of coniferous trees differs from those of broadleaved, moreover the stomatal conductance of young trees regenerating on gaps caused by the windthrow is higher because of better light conditions and their low stature (e.g. *Lorantý, M. M., Mackay, D. S., Ewers, B. E., Traver, E., & Kruger, E. L. (2010). Contribution of competition for light to within-species variability in stomatal conductance. Water Resources Research, 46(5).; Schäfer, K. V. R., Oren, R., & Tenhunen, J. D. (2000). The effect of tree height on crown level stomatal conductance. Plant, Cell & Environment, 23(4), 365-375.; Wang, R., Yu, G., He, N., Wang, Q., Zhao, N., Xu, Z., & Ge, J. (2015). Latitudinal variation of leaf stomatal traits from species to community level in forests: linkage with ecosystem productivity. Scientific Reports, 5(1), 14454.*). The tree effects altogether (effect of species, height, and light availability) have the potential to increase the nitrogen dioxide and ozone uptake in gaps created by the windthrow, compared to the mature stands.

Besides the above-mentioned concerns, I believe that the dissertation of MSc Umberto Grande entitled "Goal functions and the assessment of natural capital and ecosystem services" written under the supervision of Dr hab. Agnieszka Piernik, prof. NCU; prof. Pier Paolo Franzese; prof. (ass) Elvira Buonocore meets the requirements for doctoral dissertations specified in art. 187 of the Act of 18 July 2018 - Law on Higher Education and Science (Journal of Laws 2023 item 742) and I appeal to the Disciplinary Council of Biological Sciences of Nicolaus

Copernicus University in Toruń to admit M.Sc. Umberto Grande to further stages of the doctoral procedure.

Tomasz Szymura