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Review of the doctoral dissertation of Quadri Agbolade Anibaba MSc. entitled „Ecosystem diversity along a successional gradient of post-mining spoil heaps" prepared under the supervision of Prof. Andrzej Jagodziński and Assoc. prof. Marcin K. Dyderski from the Institute of Dendrology of the Polish Academy of Sciences in Kórnik

1. Base of the review

On the basis of Resolution No. 59/2024 of the Scientific Advisory Board of the Institute of Dendrology PAS of December 18, 2024, my person was selected as the reviewer. Subsequently, I received the letter signed by the Director of the Institute on January 2, 2025 (DN.410.2.2024) and the attached printout of the dissertation.

2. General description

The dissertation is based on three scientific articles included in journals indexed by Journal Citation Reports (JCR). The journals are an open access, payable with an total impact factor (2023) = 9.7 (range 2.3 – 3.8), five years IF = 11.8 (range 2.9 – 4.7). The total points from the Ministry of Science and Higher Education (MSHE) list published in 2024 = 440 (range 100 – 200). The articles were cited 10 times (Web of Science, accessed February 18, 2025). The subject areas of the journals were biodiversity conservation, ecology, environmental science, soil science and evolutionary biology. The publishers of the journals were Pensoft Publishers and Wiley. The articles were published in the period 2023–2024.

Those were following publications:

1. Anibaba Q.A., Dyderski M.K., Woźniak G., Jagodziński A.M. 2023. Native plant community characteristics explain alien species success in post-industrial vegetation. *NeoBiota* 85: 1–22. https://doi.org/10.3897/neobiota.85.97269 (MSHE 140 p., IF 3.8).
2. Anibaba Q.A., Dyderski M.K., Woźniak G., Jagodziński A.M. 2024. The inhibitory tendency of *Calamagrostis epigejos* and *Solidago* spp. depends on the successional

stage in postindustrial vegetation. *Land Degradation & Development* 36: 121–132. https://doi.org/10.1002/ldr.5348 (MSHE 200 p., IF 3.6).

3. Anibaba Q. A., Dyderski M. K., Woźniak G., Jagodziński A. M. 2024. Remote sensing for site selection in vegetation survey along a successional gradient in post-industrial vegetation. *Ecology and Evolution* 14, e70200. https://doi.org/10.1002/ece3.70200 (MSHE 100 p., IF 2.3).

The results come from a study carried out as part of the OPUS-18 grant with a duration of 2020 – 2025 (OPUS 2019/35/B/ST10/04141), entitled "Linking soil substrate biogeochemical properties and spontaneous succession on post-mining areas: novel ecosystems in a human-transformed landscape"), supported by the National Science Centre and led by Prof. Andrzej M. Jagodziński from the Institute of Dendrology PAS. According to the statements of the co-authors, we were informed that the contribution of the PhD student Quadri Anibaba was substantial and equal to 70% in all three publications. The following scope of work of the PhD student were mentioned in the publications: conceptualization, data curation, formal analysis, methodology, project administration, visualization, writing – original draft, writing – review and editing. He is always first author and simultaneously corresponding author. The co-authors of the three publications are the same and in the same order (1. Marcin K. Dyderski, 2. Gabriela Woźniak, 3. Andrzej M. Jagodziński).

The synthetic characterization of the research, which forms the main part of the dissertation, is limited to 19 pages, including two figures, i.e. a photograph of the successional stages on spoil heaps and a map of the distribution of the study sites.

3. Scientific value of dissertation

According to the dissertation text, the PhD student has chosen as the main objective of his work the study of vegetation diversity in post-mining landscapes and the assessment of the role of alien species and succession inhibitors on spontaneously vegetated spoil heaps. Studies object is quite common, and based on Scopus database, the sequence of keywords as "succession AND vegetation AND post AND mining AND areas" shows ca. 100 articles. Depending on the affiliation, most of the studies come from European universities, such as. Charles University in Prague, Silesian University in Katowice, Czech University of Life Sciences in Prague, and also from the Polish AGH University of Science and Technology and the University of Agriculture in Krakow. The mechanism of primary succession on heaps is well known and detailed analyses describing the model of succession are available (e.g. Prach 2001, Bradshow et al. 1997, Banaszek et al. 2017, Rahmonov et al. 2020). Nevertheless, the

mechanism of succession and the importance of these ruderal sites for the non-native species are important at the beginning when those problem ware analyse by Polish researches as Kornaś (1968), Faliński (1972), Podbielkowski 1995. Apart from the important studies on the economic and environmental conditions of artificial revegetation of spoil heaps, the main directions of reclamation are most widespread in the form of coniferous afforestation, with non-native invasive species such as black locust *Robinia pseudoacacia* also often being preferred options. This method of reclamation is authorised by the State represented by State Forests, which are the main beneficiaries of post-mining areas. This is helped by the fact that the last recommendation for the reclamation of post-mining landscapes back to 1971, in which all the invasive species conceivable at that time were proposed for planting (e.g. *Padus serotina*, *Robinia pseudoacacia*, *Caragana arborescens*). It is difficult for understanding, when one of the greatest threats to biodiversity in globe are invasive species, despite the latest studies and recommendations, including those from national universities and the faculty of forestry (e.g. University of Agriculture in Krakow), many invasive species are still common planted on spoil heaps. However, spontaneously revegetated spoil heaps face the problem of anthropophytes succession, and a robust measure is needed to evaluate the success of restoration. For this reason, I believe that this dissertation provides an additional facts for the use of spontaneous succession in the reclamation of spoil heaps verso artificial ones, that theoretically fasters, bit it is costly and the final results are threatened by not favourable environmental conditions for many plant species developments (e.g. phanerophytes).

The reviewed dissertation fits into the mainstream of research on the topic of succession in post-mining areas. The author has skilfully diagnosed the research gaps based on the earlier analysis of the literature on this topic and has put forward research hypotheses that he has consistently tested in the subsequent publications that comprise the dissertation.

The first hypothesis states that the characteristics of native plant communities can explain the abundance and frequency of non-native species. The results confirmed this hypothesis when the interaction between non-native and native species was reversed (first publication). The introduction of native species at early stages of vegetation development can reduce the level of threat posed by invasive species.

The second hypothesis assumes that dominant native species and anthropophytes inhibit the diversity of herbal vegetation at certain successional stage. The effects of *Calamagrostis* and *Solidago* on the diversity indices were evident in the middle successional stage (second publication).

The third hypothesis states that diversity (functional and phylogenetic) increases along the succession time. In the third publication, the results show that species richness and diversity were highest in the middle succession stage, but trait parameters and functional diversity reached their maximum in the late succession stages, reflecting the classical model of succession of Clements.

4. Substantive value of the dissertation

In two pages, the author provides an appropriate introduction to the topic of the dissertation (chapter 1) by explaining at the beginning the extent of the problem of the occurrence and management of post-mining areas, the models of primary succession on spoil heaps and the benefits of the research results on spoil heaps vegetation ecology. There is a lack of references for studies dealing with the model of secondary succession on spoil heaps, i.e. the development of introduced vegetation on spoil heaps that makes the restored environment more friendly to agricultural and forestry areas or rural and urban sites. Therefore, this chapter could be fulfilled for the comparison of plant community structures and the degree of synantropization on reclaimed areas with the creation of meadows with native graminoids, shrubs, constructed wetlands or tree plantations that are well adapted to the local environment. As the reclamation of spoil heaps is required by national law, they are often used for afforestation, and the comparison of this "controlled succession" with natural process could better explain the motivation of the study.

In the search for the benefits of spontaneous succession, which has been characterised by numerous studies (e.g. Bradshaw 2000, Prach et al. 2013) in which models have been developed on the effects of non-native species on plant community structure, dynamics and inhibitory effects, the author of the dissertation finds his own original space for study. The aim of the dissertation was to analyse the vegetation diversity on spoil heaps and to evaluate the role of non-native species in primary succession as inhibiting factors in spontaneously formed plant communities. Continuing this theme the following hypotheses were tested: H1: Native community characteristics will explain alien species invasion level (alien richness) and ecological success (alien cover) on spontaneously vegetated post-coal mine heaps (publication 1); H2: The inhibitory effect of invasive alien and expansive native species on diversity will depend on the successional stage (publication 2); H3: Diversity, functional and phylogenetic distinctiveness of ecosystems will increase along successional gradients (publication 3).

The study site was Upper Silesia, where the short text on the post-mining landscape, geological features and habitat conditions were presented at the beginning of the Materials and

methods chapter. I am unsatisfied with the study design and the data collection descriptions. This detailed information is also difficult to find in the three publications that contain the dissertation. It is regrettable that the number of sample plots by succession stage is not given, nor why the cluster sampling method was chosen. It would have been good to justify why doctoral candidate chose to cluster the plots instead of, for example, systematic sampling. That why arise a question - Did it make sense to include the plot clusters in the calculation of the means of all sample plots, and how did this affect the variability and error of the variables analysed? The detailed methods used to select the paths for the studies were described in the last publication. We have not information on plant communities names or dominant species of ground vegetation variability in the text of methods chapter. I also can not find any literature in the text that recommends a method for cluster sampling for the vegetation of the spoil heaps. There is also no information in the doctoral thesis about the time, seasons of the survey, which is important in vegetation science. The bryophytes layer as an important life form of the plants in the primary succession was not characterized, and it is not even stated whether it was present at all and in what cover it occurred. Their succession o bryophythes on the spoil heaps could have been important for the speed and direction of the ecological process, and the discussion about the role of moss layer in this context could be developed.

Statistical analyzes are advanced and utilize the palette of possibilities in the latest achievements in the ecological studies and statistics. Here the author's fascination with the various packages of statistical analysis was expressed, such as the ordination technique, a generalized linear mixed model, a linear mixed model, indicator species analysis, ecological indicator values, and the use of plant traits features based on appropriate lastly available databases. The various biodiversity indices, from species richness and for understanding important aspects of functional community structure, the author combined plant trait data with species coverage to calculate community weighted means and functional diversity indices. This part of the text deserves underlining and is a valuable and innovative part of the work.

The results contain a coherent presentation of the publications contained in the dissertation. The same references are included. The results obtained show that native species influence the degree of succession of non-native species. The occurrence and development of non-native species was limited by the increase in the coverage of native species, while the richness and coverage of invasive species increased with the functional richness of native species. Of the studied plant communities on the spoil heaps, those in the early stages of succession are most threatened by non-native species, and active management could be applied during this period (publication 1). The developed analysis shows the negative impact of succession inhibitors on

diversity indicators. The author selected two elements of herbal flora as inhibitors, and the results showed a strong impact, but dependent on the successional stage on spoil heaps. The effect determined by GLMM showed that *Calamagrostis epigejos* and *Solidago* spp. have an influence on the diversity indicators in the middle succession stage. At this successional stage, the number of species and functional richness decreased significantly with the abundance of *Calamagrostis* and *Solidago*. On the other hand, Shannon diversity decreased slightly, while phylogenetic diversity increased slightly with *Calamagrostis* cover. Shannon's diversity was negative, while phylogenetic diversity was positively correlated with *Solidago* coverage (publication 2). Species richness followed an arch-shaped pattern: they were highest in the middle succession and lowest in the late succession stages. Functional composition differed significantly in late succession stages in terms of light ecological indicator value, soil fertility, community weighted means for plant height and specific leaf area index. The late succession vegetation had the lowest functional richness and the highest functional dispersion simultaneously (publication 3).

While the presentation of the results itself contains the answers to the hypotheses, there is no chapter dedicated to the discussion of the results of the individual articles.

The chapter with the most important conclusions answers for the aim and the hypotheses. The first part of reviewed text contains the general statement to the significance of the studies conducted within the doctoral dissertation. The listed conclusions are the summary of the results mentioned in the previous chapter. The last sections of this chapter contain the conclusion on the application aspects of the study results. This recommendation is related to the results of the second publication on the role of inhibitor species such as *Calamagrostis epigejos* and *Solidago* spp. However, the statement that management measures should be planned in the mid-succession stages because biodiversity is threatened by succession inhibitors does not correspond to the results of the first publication again. It states: "…at the early stage of spontaneous vegetation development are the most threatened by alien species, thus requiring active management and conservation". Here we should rather use more balanced conclusion, conditioned by local conditions and species pools.

What is need to underline, that the conclusions ware corelated very strictly with obtained results. Many times I could observe, that those tendency of conclusion edition is quite rare. More common is to use general concussions of doctoral thesis, that are not directly connected with the results.

The bibliography of dissertation is relatively extensive and contains 76 articles in English. In my opinion, the choice of literature is apt, for on the one hand we find a number of articles

from which the author build him capacity knowledge. These include methodological technics with descriptions and algorithms, but also important studies on vegetation succession. On the other hand, there are a high number of recent research results on the succession and management of post-mine areas, which are important for the discussion of the results.

5. Evaluation of the formal side of the dissertation

The dissertation contains a very well-written introduction that provides an overview of all aspects of the object of study. Novel is the presentation of the aims and the hypothesis, where we could find short but meaningful premises after the hypothesis, in which references support the hypothesis verification. After the introduction and methods, the summary of the results from the publication, a discussion chapter should follow before the conclusions. Although there are elements of discussion of the results in the main results chapter, they could be better placed in separate part of the dissertation.

The text of the dissertation is short but clear and therefore does not directly repeat content from publications, which is desirable. Occasionally the author uses personal forms, e.g. “My dissertation fills...”, where it should normally use non-personal forms.

If we look at the order of publications within the dissertation and its workflow, publication no. 3 could be placed at the beginning. This is because from it we can see the detailed procedure for selecting clusters for sampling. The use of remote sensing is not stated as an objective of dissertations, but indices of features are calculated and the types of succession stages are included. In the first publication, this procedure was described in very general terms.

6. Problem questions

In light of the above deliberations and obtained results in thesis, I would like to ask the doctoral candidate three questions:

1. How might cluster sampling affect the variance and errors of the obtained descriptive statistics of the vegetation structure of paths in spoil heaps compared to systematic sampling?
2. What type and time of measures (ecological engineering), tree and shrub species for afforestation, could you recommend for abandoned spoil heaps that will limit succession of invasive species?
3. What the environmental conditions limit the use of spontaneous succession in the reclamation of post-mining sites?

7. Final assessment

The above suggestions and criticisms do not change my positive opinion about the dissertation.

I conclude that the peer-reviewed dissertation by MSc. Quadri A. Anibaba fulfils the conditions laid down in Polish law, i.e.:

- provides an original solution to the scientific problem of studying vegetation diversity in post-mining landscapes and assessing the role of non-native species and succession inhibitors on spontaneously vegetating spoil heaps,
- demonstrates knowledge in the discipline of biosciences, especially in plant ecology,
- confirms that doctoral candidate student is able to conduct scientific research independently, as evidenced by the performance of the majority of field and labor work within the research project, including the elaboration of results using correctly chosen and advanced methods, as well as by the leading role in the preparation of scientific publications forming the basis of the dissertation.

According to above statements, I conclude that peer- reviewed doctoral dissertation of MSc. Quadri Agbolade Anibaba meets the conditions specified in Article 187 of the Act of July 20, 2018 Law and Higher Education and Science (i.e. Journal of Laws of 2023, item 742, as amended), and I request the Scientific Council of the Institute of Dendrology of the Polish Academy of Sciences to admit MSc. Quadri Agbolade Anibaba to further stages of the proceedings for the conferment of the doctoral degree.

Janusz Czerepko

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