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Review of the doctoral dissertation: „Ecosystem diversity along a successional gradient of post-mining spoil heaps" by MSc Quadri Agbolade Anibaba

The doctoral dissertation has been conducted in the field of natural sciences in the discipline of biological sciences under the supervision of prof. dr hab. Andrzej M. Jagodziński and dr hab. inż. Marcin K. Dyderski at the Department of Ecology of the Institute of Dendrology, Polish Academy of Sciences. The dissertation is based on three original scientific papers published in high-ranked international journals – NeoBiota (IF_5 = 4.2), Land Degradation and Development (IF_5 = 4.7), and Ecology and Evolution (IF_5 = 2.9). All publications have four authors and in all publications PhD candidate Quadri Agbolade Anibaba, MSc is the first and corresponding author with a high contribution estimated at 70%. The dissertation consists of the above-mentioned publications, abstracts in Polish and English, longer description of the study including introduction, research objectives and hypotheses, material and methods, main results divided into three sections, and main conclusions. The dissertation also includes co-author statements on their contribution to the publications.

Most post-mining sites are subjected to technical reclamation, which typically comprises of covering the ground with fertile topsoil, sowing mixtures of herbaceous plant species, and planting trees. Such management may waste the conservation potential of post-mining sites. Spontaneous succession or directed succession is an alternative restoration approach. Succession may lead to the development of valuable ecosystems consisting of organisms adapted to harsh environmental conditions of post-mining sites. In Poland, calamine grasslands that occur on soils with a high content of heavy metals, mainly Cd, Pb, and Zn, are an example of such valuable and interesting communities. However, areas heavily disturbed by human activity are prone to the encroachment of undesirable invasive or expansive plant species. Therefore, it is crucial to understand plant-plant interactions in novel

ecosystems, factors driving the resistance of plant communities to the encroachment of alien plant species, and to implement adequate management practices in post-mining sites.

The study performed by PhD candidate Anibaba is a new and original contribution to our understanding of ecosystems development in post-mining areas. It has strong theoretical background, indicating candidate's extensive knowledge on the research problem. The aim of the first part of the study (Publication 1) was to answer the questions which alien species are the most successful on the post-mining heaps and why, what are the factors driving alien species richness and cover, and how are they affected by the native community, and what implications it has for predicting threats from alien species and management. It was hypothesized that native community characteristics explain alien species invasion level (alien richness) and ecological success (alien cover) on spontaneously vegetated post-coal mine heaps. The aim of the second part of the study (Publication 2) was to assess the inhibitory roles of alien and native species. It was hypothesized that the inhibitory effect of invasive alien and expansive native species on diversity will depend on the successional stage. Third part of the study (Publication 3) was focused on the usefulness of remotely sensed data in classification of vegetation in post-mining area. It was hypothesized that remote sensing-based vegetation clusters will differ in alpha diversity, species, and functional composition, providing an ecologically interpretable division of study sites for further analysis. The diversity, functional, and phylogenetic distinctiveness of ecosystems will increase along successional gradients.

The study performed by PhD candidate Anibaba is extensive. The number of heaps and vegetation patches is a solid basis for a study and allows drawing reliable conclusions on the research problem. After the selection of 60 heaps in the post-coal mining area, Landsat satellite imagery was acquired to obtain vegetation indices of the spoils. Five vegetation clusters were obtained and eighty vegetation patches were selected for the study in the post-coal mining area in the Upper Silesia. Each patch consisted of five plots, giving 400 plots in total. In the plots, plant abundance was estimated. Plant functional traits associated with plant competitive ability, dispersal, establishment, and stress tolerance, along with plant species cover were used to calculate indicators that were further used as predictors of community invasibility. The data collected were subjected to in-deph statistical analyses.

In publication 1, vegetation survey showed 318 vascular plant species, of which 20% were alien species. The most frequent alien species were *Erigeron canadensis*, *Solidago gigantea*, *Solidago canadensis*, *Erigeron annuus*, and *Impatiens parviflora*. The most important alien species were *Solidago gigantea* and *Impatiens parviflora* as they had the

highest mean cover. It was shown that the best predictor of alien species richness (i.e., species invasion level) was native functional richness (positive relationship) and the best predictor of alien species cover (i.e., ecological success) were native species cover (negative relationship), native functional richness, native community-weighted seed mass, and native community-weighted plant height (positive relationships). Management practices on post-coal mining heaps should include native species addition at the early successional stage. It was shown (Publication 2) that alien invasive *Solidago* spp. and native expansive *Calamagrostis epigejos* did not exhibit limiting effects on diversity indices (taxonomic, functional, and phylogenetic diversity) across all three successional stages. The effect depended on the stage and was observed only in the middle succession stage. The third part of the study (Publication 3) showed differences in functional diversity between remote-sensed clusters. They followed successional development. The increasing importance of competition with the succession advancement was showed.

The study performed by Quadri Agbolade Anibaba, MSc is excellent and the doctoral dissertation is very well written. As it has been published in high-ranked international journals as three publications, it has been already reviewed and revised according reviewers' suggestions. Therefore, I have only minor comments or questions to the dissertation.

I am not convinced if the title of this dissertation is adequate to its content. "Ecosystem" is a broad term; the dissertation was actually focused on plant communities.

Publication 1, Table1: EIV abbreviation should be explained. It is not clear if nitrogen is a trait of a plant or of its habitat (i.e., soil).

Publication 2: Why successional classes of heaps overlap (early stage 1-8 years, mid-stage 6-14 years)

I also wonder if plant traits associated with chemical characteristics of their tissues (N and P contents, C/N ratio, phenolics content), which were not included in this study, can be useful predictors of community invasibility or the potential of species to be invasive?

Could the analysis of chemical and/or (micro)biological properties of post-mining material and/or soil along with the plant data collected increase our understanding of novel ecosystem development?

In my opinion, the quality of the study is very high. The study is novel, very extensive, has strong theoretical background, and perfect statistics. The interpretation of results and discussion is correct. The dissertation is very well written. The results not only improve our insight into the problems of novel ecosystems developing at post-mining sites but also have practical implications. Management of sites restored via spontaneous succession should aim at

reducing the invasibility in the early- and mid-successional stages. Native species addition should be encouraged, specifically at the early successional stage.

Therefore, I conclude that the reviewed doctoral dissertation by Quadri Agbolade Anibaba, MSc, meets the conditions specified in Article 187 of the Act of July 20, 2018 Law on 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 Quadri Agbolade Anibaba, MSc to further stages of the proceedings for the conferment of the doctoral degree.

Stwierdzam, że recenzowana rozprawa doktorska mgr. Quadriego Agbolade Anibaby spełnia warunki określone w art.187 ustawy z dnia 20 lipca 2018 r. Prawo o szkolnictwie wyższym i nauce (Dz. U. z 2023 r. poz. 742 z późn. Zm.) i wnioskuję do Rady Naukowej Instytutu Dendrologii Polskiej Akademii Nauk o dopuszczenie mgr. Quadriego Agbolade Anibaby do dalszych etapów postępowania w sprawie nadania stopnia doktora.

Due to the very high quality of the research and publication of the results in very good international scientific journals, I request the Scientific Council of the Institute of Dendrology of the Polish Academy of Sciences that the doctoral dissertation by Quadri Agbolade Anibaba, MSc is accepted with distinctions.

Ze względu na bardzo wysoką jakość badań oraz opublikowanie wyników w bardzo dobrych czasopismach naukowych o międzynarodowej renomie wnoszę do Rady Naukowej Instytutu Dendrologii Polskiej Akademii Nauk o wyróżnienie rozprawy doktorskiej mgra. Quadriego Agbolade Anibaby.

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