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4 1 **A brief comment on “International Principles and Standards for the Ecological**  
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6 2 **Restoration and Recovery of Mine Sites” – useful but limited**  
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9 3 **Running head: Useful but limited Mining Standards**

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54 19 wrote the final version.

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## 21 **Abstract**

22 The Principles and Standards by Young et al. (2022) provide an international framework for  
23 ecological restoration of mine sites. Although useful, these Standards are limited as a basis for  
24 practice, especially in Europe, partly by neglecting the fact that secondary habitats are often  
25 desirable restoration targets in anthropogenic cultural landscapes; intermediate and early  
26 successional stages are sometimes more ecologically valuable than terminal stages;  
27 spontaneous succession can be the most effective restoration approach or may be combined  
28 with assisted restoration; and by presenting a limited number of representative long-term  
29 restoration case-studies. Further efforts to create consensual guidelines require a broad  
30 discussion across biomes, regions and public and private sectors. Meanwhile, the Standards  
31 should be regarded as a tentative academic-oriented framework with some substantial  
32 limitations for practice.

## 34 **Implications for practice**

35 Adaptations of mining standards are required for particular regions.  
36 Secondary habitats of the cultural landscape may represent desirable restoration targets.  
37 Not only terminal but also intermediate and early successional stages can be valuable.  
38 Spontaneous succession should be considered more, where possible.  
39 A practice-oriented framework based on consensus between stakeholders is necessary.

41 **Keywords:** Europe, human-made landscape, legislation, restoration success, semi-natural  
42 habitats, spontaneous succession

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3 43 International standards should be the basis for good practice in ecological restoration worldwide  
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5 44 but need to be adapted to the particular conditions of each region. We welcome the publication  
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7 45 of the Principles and Standards presented by Young et al. (2022) summarizing knowledge  
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9 46 available for ecological restoration of various post-mining sites. However, the content of the  
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11 47 Standards is based on experience mostly gained from North America, prevailingly from the  
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13 48 United States, and Australia. Although we share many points, Europe, which has been rather  
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15 49 neglected both in examples and references in the Standards, differs to some extent from the  
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17 50 mentioned continents and thus the Standards cannot be fully adopted there.  
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22 51 Europe is a largely human-made landscape mostly depleted of pristine ecosystems and the  
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24 52 targets of restoration are often semi-natural ecosystems (Welzholz & Johann 2007, Lundholm  
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26 53 & Richardson 2010). Most of the European landscape has been subject to rather intensive  
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28 54 human impact since at least the beginning of the Neolithic period nearly eight thousand years  
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30 55 ago (Poschlod 2015, Roberts et al. 2018), while North America and Australia were largely  
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32 56 covered by more or less natural vegetation until the 19<sup>th</sup> century (Gajewski et al. 2019). Natural,  
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34 57 undisturbed vegetation still survives there in some places, often near post-mining sites, and may  
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36 58 well represent reference and target sites with high diversity. By contrast, in Europe, a variety  
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38 59 of secondary habitats have developed after continuous human pressure, e.g. hay meadows and  
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40 60 pastures in the temperate zone or pseudo-steppes and agro-silvopastoral systems in the  
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42 61 Mediterranean zone (Marañon 1988), which harbor the highest level of biodiversity in both  
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44 62 temperate (Wilson et al. 2012) and Mediterranean Europe (Buisson et al. 2020). Thus, the  
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46 63 potential natural vegetation, i.e. the theoretical terminal successional vegetation corresponding  
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48 64 to site conditions (Somodi et al. 2021) may not always be the primary target of restoration.  
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50 65 Instead, an alternative state related to secondary habitats of the European cultural landscape  
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52 66 may often be preferred (Siles et al. 2010, Tischew et al. 2014).  
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3 67 We are convinced that too much emphasis is placed on restoration of late or terminal  
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5 68 successional stages in the Standards. In Europe, this would mean coniferous forests in the north,  
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7 69 evergreen woodlands or maquis in the south, steppes in the east, and deciduous broadleaved  
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9 70 woodlands in most of the rest of Europe (Bohn et al. 2000). However, not only closed late-  
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11 71 successional vegetation but also intermediate successional stages with limited tree  
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13 72 establishment, or even initial and early successional stages shortly after a disturbance by mining  
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15 73 may be of great conservation value (Baasch et al. 2012, Alday et al. 2022, Münsch & Fartmann  
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17 74 2022). The European landscape is heavily eutrophicated causing altered soil dynamics and  
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19 75 shifts in species composition (Bobbink et al. 2010). Conversely, mining may create nutrient-  
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21 76 poor sites serving as surrogate habitats for competitively weak species which are in steep  
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23 77 decline in the surrounding landscapes (Kirmer et al. 2008). These species are often rare and  
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25 78 endangered red-listed specialists (Twerd et al. 2021). However, there is a precondition that  
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27 79 neither nutrient-rich organic material, usually topsoil, nor saplings or seeds of less specialized  
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29 80 and competitive species are introduced to mining sites. In central Europe, Řehouňková et al.  
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31 81 (2020) demonstrated that out of 271 Red List species occurring at various spontaneously  
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33 82 restored post-mining sites, a great majority (223) avoided closed woodlands which had  
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35 83 naturally developed in late successional stages. In this sense, we do not agree with the statement  
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37 84 in the Standards that “the goal should be to achieve the highest level of recovery possible at a  
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39 85 site” (p. 27), but would recommend aiming at the highest level of biodiversity and ecosystem  
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41 86 functions possible for a specific successional stage.  
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50 87 We also think the strong bond between some special soils, such as serpentine, gypsum or  
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52 88 metalliferous outcrops, and specialized biota occurring on and in mined resources has been  
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54 89 overlooked in the Standards. There is a long evolutionary history of adaptation of plants and  
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56 90 soil microbiota to particular edaphic substrates (Rajakaruna 2004, Hulshof & Spasojevic 2020).  
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58 91 These substrates, if available after mining (e.g. not depleted or covered by topsoil), may  
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3 92 constitute important habitats for unique flora and other organisms (Ballesteros et al. 2014,  
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5 93 Boisson et al. 2017).

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9 94 We are also convinced that spontaneous (passive) restoration of post-mining sites, i.e. an  
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11 95 approach relying on natural succession without intentional human influence, is rather  
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13 96 underestimated in the Standards. In a worldwide meta-analysis of 74 different successional  
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15 97 series covering at least several decades at post-mining sites, Prach & Walker (2020) clearly  
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17 98 demonstrated that spontaneous succession used as a restoration tool was successful in reaching  
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19 99 the target in 54% of cases, while it was partly successful in 34%, and failed in only 12% of  
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21 100 cases. The 'success of succession' was defined as the ability to reach a target, i.e. the  
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23 101 establishment of particular potential natural vegetation or another targeted state desirable for  
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25 102 restoration, within 100 years, and the presence of weeds and aliens was unimportant in the  
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27 103 target stages. This work also proved that spontaneous succession at post-mining sites was the  
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29 104 most successful in the temperate zone and the least in Mediterranean-type ecosystems. This  
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31 105 means that in Europe we can largely rely on spontaneous succession in its temperate zone,  
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33 106 which should also be considered in restoration projects. Similarly, we are convinced that the  
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35 107 combination of assisted and spontaneous succession should be considered in Mediterranean  
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37 108 ecosystems. The only European study presented in the Standards from Kiruna in northern  
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39 109 Sweden, i.e. from the boreal zone of Europe, is not really representative of European conditions.  
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46 110 Spontaneous succession generally selects species which are adapted to a disturbed site much  
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48 111 better than those selected by people in assisted restoration or reclamation (Bradshaw 2000). It  
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50 112 must be appreciated that the authors of the Standards mention the use of natural restoration,  
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52 113 natural regeneration and succession (sensu spontaneous succession) but we miss clear  
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54 114 recommendations of how to apply the concept of spontaneous succession under different  
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56 115 environmental conditions and in various landscapes and regions, i.e. including those where  
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58 116 native ecosystems or their fragments are missing (Prach et al. 2020). On the other hand, we are  
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3 117 aware that spontaneous succession is not the best option everywhere and assisted succession  
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5 118 could be an option under certain circumstances (e.g. lack of seed sources, invasive species  
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7 119 abundant in the surroundings) but it could be applied whenever possible, among other reasons  
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10 120 to save labor and money.  
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13 121 We would further like to highlight the importance of long-term monitoring of restored sites,  
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15 122 especially if selected as case studies for a broader audience and encourage in the Standards a  
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17 123 larger representation of case studies based on long-term rather than envisaged monitoring.  
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19 124 Short-term data can lead to misinterpretation of the restoration results because quite different  
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21 125 trends may occur after a decade or later as documented by Pospíšilová et al. (2022). Also, short-  
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23 126 term results may promote unnecessary management at higher economic and even  
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25 127 environmental costs (Oliveira et al. 2011). Therefore, we recommend careful selection of case  
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27 128 studies which give evidence of a particular phenomenon or trend and are documented by  
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29 129 representative and if possible statistically tested data obtained by means of long-term  
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31 130 monitoring.  
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37 131 We appreciate the inclusion of a chapter dealing with social aspects of restoration projects. The  
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39 132 acknowledgement of the culture and rights of indigenous people is a topic of major concern in  
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41 133 several continents, however lesser so in Europe. The Saami, previously known as Laplanders,  
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43 134 are the only recognized indigenous people of Europe living in the northern part, i.e. Norway,  
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45 135 Sweden and Finland (Tuori 2015). Thus, the case study located in Kiruna, northern Sweden  
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47 136 represents a very specific example. On the other hand, we miss a general focus on legislation  
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49 137 concerning mining and restoration, which we regard to be one of the main barriers to the  
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51 138 application of scientific approaches to the restoration of European mining sites (Cortina-Segarra  
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53 139 et al. 2021). The diverse legislation in European countries makes the implementation of  
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55 140 procedures and standards even more complicated. Therefore, a brief overview of the current  
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57 141 state of the art across the different continents with some recommendations for the practitioners  
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3 142 would contribute to more realistic targets, e.g. definition of a minimum restored area of a post-  
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5 143 mining site for the purpose of nature conservation. We hope that the Nature Restoration Law,  
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7 144 currently under negotiation among the European Union countries, will help in this respect in  
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10 145 the near future.

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13 146 In conclusion, Standards should be adapted to the European context and modified to make it a  
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15 147 more practical document after a broad discussion with a balanced selection of representatives  
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17 148 across the biomes, regions and public and private sectors (FAO, IUCN, CEM & SER 2021).  
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19 149 The leading role in this adaptation process should be coordinated by a well-qualified team  
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21 150 serving as a restoration hub at the European level. In the meantime, the Standards as presented  
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23 151 by Young et al. (2022) should in Europe be regarded as a tentative, prevalingly academic-  
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25 152 oriented framework with some substantial limitations.

### 30 153 Acknowledgements

31  
32  
33 154 We were supported by funding from the Grant Agency of the Czech Republic (Grant no. 20-  
34  
35 155 06065 S). We thank our colleagues for valuable discussion on the topics presented here, and  
36  
37 156 Jan Willem Jongepier for language revision.

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