

## RESEARCH ARTICLE

# Enhancing biodiversity and ecosystem services in quarry restoration – challenges, strategies, and practice

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Although covering less than 1% of the land surface, extraction activities have long-lasting impacts on local ecosystems, inevitably damaging biological diversity and depleting ecosystem services. Many extractive companies are now aware of their impacts and, while pressured by society, demand concrete solutions from researchers to reverse the effects of exploitation and restore biodiversity and ecosystem services. In this article, we compile and synthesize the contributions of the latest available research on quarry restoration. We depict and discuss some of the most pressing issues regarding (1) the challenges of restoring quarries; (2) the opportunities for biodiversity and ecosystem services delivery; and (3) outline further research addressing current gaps. We conclude that quarries pose different abiotic and biotic constraints that act interdependently, hampering the attainment of effective restoration if considered solely. Such constraints need to be addressed holistically to lastly encourage the self-sustainability of the system by reinstating ecological processes. However, a restored site does not have to specifically mimic the pristine situation, as under certain conditions alternative approaches may uphold valuable natural assets contributing to the conservation of rare, restricted, or protected species and habitats.

**Key words:** assisted restoration, ecosystem restoration, management practices, nature conservation, nature-based solutions, non-energy extractive industry, spontaneous succession

## Implications for Practice

- All is connected: soil and landform directly affect productivity and environmental conditions, which will determine vegetation and animal communities able to colonize and thrive in these human-made systems.
- Fully functional and self-sustainable ecosystems are usually the aim of active restoration but less advanced stages may also be of restoration interest.
- Alternative approaches, such as spontaneous succession, may provide a valuable contribution to nature conservation and ecosystem services, while avoiding expensive restoration or reclamation practices.
- Quarrying activity should not prevail over conservation of threatened ecosystems, especially if the post-restoration state cannot compensate for the lost natural assets.

## Introduction

Increasing demand for natural resources has been fueling the growth rates of resource extraction, contributing significantly to biodiversity loss (IRP 2019). Despite the several global agreements (UN, Aichi Targets), biodiversity continues to change globally (Butchart et al. 2010; Dornelas et al. 2014; Tittensor et al. 2014), with ongoing species loss and/or changes in communities (e.g. species turnover, homogenization). Our knowledge is still too limited to understand the exact consequences of these changes for human well-being and ecosystem

resilience, presently and in the future (Branquinho et al. 2019). In response, the United Nations advocated on 1 March, 2019, the 2021–2030 period as the “Decade on Ecosystem Restoration” (UNEA 2019). Although valuable it may be, it leaves us a worrying sign: is no longer enough to protect, we must also restore!

The non-energy mineral extraction sector, for instance, has grown 2.7 and 8.3% per year since 1970 for metals and non-metallic minerals, respectively (IRP 2019). Although covering less than 1% of the land surface (Walker 1999), this sector has critical and long-lasting impacts on local ecosystems. Extraction activities inevitably damage ecosystems resulting in biodiversity loss or change and the depletion of ecosystem services. Restoration (either spontaneous or assisted) stands as a solution to reverse mining and quarrying impacts, thus contributing to

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