

Accepted Manuscript

Soil quality indicators: a critical tool in ecosystem restoration

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PII: S2468-5844(17)30034-X

DOI: [10.1016/j.coesh.2018.04.007](https://doi.org/10.1016/j.coesh.2018.04.007)

Reference: COESH 42

To appear in: *Current Opinion in Environmental Science & Health*

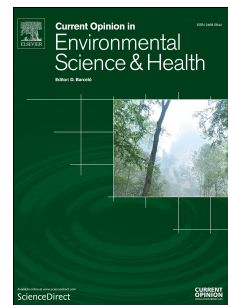
Received Date: 15 February 2018

Revised Date: 23 April 2018

Accepted Date: 27 April 2018

Please cite this article as: Muñoz-Rojas M, Soil quality indicators: a critical tool in ecosystem restoration, *Current Opinion in Environmental Science & Health* (2018), doi: 10.1016/j.coesh.2018.04.007.

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1 **Soil quality indicators: a critical tool in ecosystem restoration**

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8 **Abstract**

9 Soils provide multiple functions that support the delivery of key ecosystem services such as climate and water
10 regulation, carbon sequestration, or nutrient cycling. These functions can be seriously affected in degraded
11 ecosystems, and the global community has accordingly set specific targets for ecosystem restoration. Most soil
12 ecosystem functions are difficult to assess directly and must be inferred from measurable soil properties, i.e. soil
13 quality indicators, which can cover a broad range of soil physical, chemical, and biological characteristics.
14 Developing clear goals for restoration and defining effective tools to assess and monitor progress, are critical to
15 achieve restoration success. Soil quality indicators can be a valuable asset for ecosystem monitoring and
16 assessment in restoration programs, predominantly with respect to understanding the role of soil properties and
17 plant–soil relationships that promote revegetation. Recent advances in the development of methodologies for soil
18 analyses, including soil sensing techniques or molecular methods, provide unprecedented opportunities to further
19 unravel plant-soil feedbacks and interactions during ecosystem recovery. However, despite the substantial
20 potential benefits of using soil quality indicators as tools in ecosystem restoration, the calibration and
21 establishment of global parameters remains a challenge due to the large variability in soil, climate, and ecosystem
22 types. This review provides an overview of the current knowledge of soil quality indicators in the context of
23 ecosystem restoration. Examples of relevant soil physicochemical and microbiological indicators, and current and
24 novel methodologies for their assessment, are presented. Furthermore the benefits and challenges for the global
25 integration of these indicators in ecosystem restoration programs are discussed.

26 **Keywords**

27 Soil health, soil organic carbon, soil microbial communities, Sustainable Development Goals (SDGs), land
28 degradation

29 **Introduction**

30 Land degradation and loss of biodiversity are two of the most pressing global problems affecting terrestrial
31 ecosystems [1]. Approximately 23% of the globe's terrestrial surface is currently affected by some form of
32 degradation, with 5-10 million additional ha being affected annually, and about 1.5 billion people negatively

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