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1 **Restoration and Rehabilitation of Degraded Land in Arid and Semi-Arid**
2 **Environments: Editorial**

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22 Widespread degradation is impacting land at the global scale as a consequence of intense
23 anthropogenic pressures and accelerated changes in climate. The expansion of land
24 degradation may cause the destabilization of ecosystems' structure and functioning and may
25 be somewhat comparable to a global health crisis such as the covid19 pandemic (Di Marco
26 et al., 2020). Although areas of high biodiversity can host high numbers of pathogens,
27 biodiversity may serve as a protective factor for preventing transmission and maintaining
28 ecosystems helping to reduce exposure to infectious agents (Romanelli et al, 2015). Recently
29 it has been suggested that degraded habitats may encourage more rapid evolutionary
30 processes and diversification of diseases allowing pathogens to spread easily to livestock and
31 humans (Zohdy et al., 2019). Thus, conserving, or in the case of irreversible degradation,
32 restoring, are the goals that society has to enforce to maintain or rebuild an equilibrium with
33 nature. Particularly susceptible regions are drylands, which include arid and semi-arid

34 environments. These areas are largely affected by climate change and land degradation
35 impacts (Berdugo et al., 2020) with ecosystems facing serious threats such as long periods of
36 drought, unpredictability of rainfall, and intense use of the land.

37 The capacity of ecosystems to regenerate is limited, and therefore restoring degraded land is
38 becoming essential to repair the integrity of impacted forests, rangelands, mine-affected
39 areas) and numerous habitats around the globe (Ockendon et al., 2018). Land restoration and
40 rehabilitation can enhance the natural capital of land and the provision of soil ecosystem
41 services play a key role for climate change mitigation as well as adaptation (Hobley et al.,
42 2018; Nunes et al., 2016). This special issue of *Land Degradation & Development* compiles
43 23 articles reporting research conducted across all global geographic regions except
44 Antarctica, i.e. Africa, Asia, Australia/Oceania, Europe, North America and South America.
45 These papers address current and upcoming challenges and opportunities for the *Restoration
46 and Rehabilitation of Degraded Land in Arid and Semi-Arid Environments*.

47 The United Nations (UN) General Assembly adopted a resolution in March 2019 declaring
48 2021-2030 the UN Decade on Ecosystem Restoration (Willemen et al., 2020). This global
49 call for action is expected to bring together scientific research and political and administrative
50 efforts to scale up restoration in the upcoming years. This resolution has been preceded by
51 several initiatives to reverse land degradation such as the Convention on Biological
52 Diversity's Aichi Targets, the Bonn Challenge and its regional initiatives to restore more than
53 150 million hectares of land; and most recently the 2030 Agenda for Sustainable
54 Development and the Sustainable Development Goals (SDGs) (Bateman and Muñoz-Rojas,
55 2019). One of the challenges identified by the SDGs is the need to define appropriate
56 indicators for measuring the progress towards achieving the goals proposed, and to
57 understand which areas to prioritise and allocate resources to (Ockendon et al., 2018; Nunes
58 et al., 2016).

59 Defining suitable indicators for monitoring and assessing the success of restoration should be
60 a priority within restoration programs as highlighted in this issue (Bateman et al., 2018;
61 Shackelford et al. 2018). However, monitoring restoration success is often challenged by the
62 complexity and scales of studies over time. (Costantini et al, 2016). Some countries like
63 China are currently tackling extensive land degradation caused by agricultural pollution and
64 rely on indicators to assess the sustainability of agricultural remediation. In their paper, Hou
65 et al. (2018) review the state of these assessments and discuss the social, economic,

66 environmental, and agricultural implications within the complex human-environmental
67 system. Their study remarks that the implementation of action plans for land remediation
68 needs to consider social aspects and the implications for long-term sustainability. An
69 increasing number of studies are showing the importance of long-term monitoring in
70 restoration (Shackelford et al. 2018), as vegetation establishment and soil properties can go
71 through transient states over time and may evolve over decades (Yu and Wang, 2018). At
72 landscape scales, geomorphic analysis and remote sensing techniques provide sensitive
73 satellite-derived indices that can offer multiple possibilities for monitoring studies at such
74 large ranges. This is well exemplified in Xu et al. and Murthy and Bagchi (2018).

75 A group of articles in this issue, is focused on revegetation techniques. Revegetation has been
76 for many years a conventional strategy for rehabilitation of degrading landscapes (Hobley et
77 al., 2018) and using native plants adapted to drought can facilitate plant establishment in
78 degraded soils under water stress conditions (Bateman et al., 2018). Revegetation efforts
79 generally result in improvement of soil fertility and enhancement of ecosystem services and
80 functions such as carbon sequestration (Gao et al., 2018), nutrient cycling (Barliza et al.,
81 2018 Hu et al., 2018) and soil microbial diversity and activity (García et al., 2018; Liu et al.,
82 2019); nevertheless, it can also lead to adverse effects such as salinity which may affect the
83 success of restoration efforts in the long term (Yu and Wang, 2018). Some native plants such
84 as halophytes, may on the other hand assist in the remediation of salt-affected soils (Shaygan
85 et al., 2018) (Figure 1). Applying vegetation buffer strips can be an effective measure for
86 reducing erosion and soil nutrient movement in degraded hillslopes (Kavian et al., 2018).
87 However, the establishment of vegetation in large-scale rehabilitation operations may not be
88 sufficient to support new and economically driven developments in the construction of
89 landforms with increased spoil elevation, and detailed geological information is essential in
90 these instances (Emmertson et al., 2018).

91 A large share of articles in this issue evaluates the use of amendments in restoration. The use
92 of amendments in restoration programs is being increasingly encouraged because of their
93 positive effects on soil physical, chemical and biological characteristics (Hueso et al., 2018).
94 Organic amendments such as biosolids, composted material and mulches may increase soil
95 microbial activity, which favor organic matter decomposition and mineralization, and
96 generally increases plant productivity and carbon sequestration in the medium or long-term,
97 as highlighted in this issue by Valdecantos and Fuentes (2018). Also in this issue, Luna et al.
98 (2018), show that woodchip mulch can be effective for trapping runoff and sediment in mine

99 rehabilitation sites whereas organic amendments formed by composted waste can improve
100 infiltration and reduce water erosion (Figure 2). There are, however, risks associated with the
101 use of these techniques and the source of these amendments, which may incorporate potential
102 contaminants such as heavy metals or polycyclic aromatic hydrocarbons that are often
103 overlooked (Carabassa et al. 2018). Importantly, the practice of using locally sourced
104 amendments can also contribute to the circular economy reducing the amount of exogenous
105 fertilizers and contributing to climate change mitigation (Hueso Gonzalez et al., 2018). In
106 socio-economically developing regions, organic amendments such as native mulches can be
107 in fact one of the few available options for improving soil fertility as dicssued in this issue by
108 Félix et al. (2018) and Ndegwa et al. (2018). Félix et al. (2018) show that adding a native
109 shrub, e.g. ramial wood, in high volumes could sustain crop yields in Burkina Faso. Yet, the
110 amount of biomass needed exceeds the available capacity in the landscape and afforestation
111 would be needed to support food production. Similarly, charcoal demand is growing in
112 developing countries because of the lack of alternative energies which exerts a high pressure
113 on available forest resources. To address this issue, Ndegwa et al. (2018) propose a
114 sustainable plan for wood harvesting considering the annual biomass increment of
115 woodlands.

116 A final group of articles documents examples of innovative approaches and technologies used
117 in restoration. Thesen novel methods include the use of polymers (Liao et al., 2108) and bio-
118 inoculants such cyanobacteria that form biocrust (Roman et al., 2018) and endophytic
119 bacteria (Galaviz et al., 2018). As an alternative to compost application, Galaviz et al. (2018)
120 inoculated degraded desert soils with the endophytic bacteria *Bacillus pumilus*, which
121 resulted in an increase of the *Rhizobium* population in the soil. Roman et al. (2018) highlight
122 in their study the potential of inoculated N-fixing cyanobacteria from soil biocrust to increase
123 soil C and N in semi-arid degraded soils (Figure 3). With advanced tools such as highly
124 specified molecular technologies, these approaches have expanded from the agricultural and
125 biotechnological sectors to the fields of ecosystem restoration and land rehabilitation opening
126 new possibilities in these research areas (Muñoz-Rojas, 2018).

127 Most of the papers published in this special issue were presented at the European
128 Geosciences Union Assembly in Vienna, Austria, in April 2017. All manuscripts were
129 externally peer reviewed in accordance with *Land Degradation & Development* guidelines.
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134 **Conflict of interest**

135 The authors declare no conflict of interest

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260

261 **Figure captions**

262 **Figure 1.** Halophytes tolerating and self-remediating saline soil conditions in Eramonga,
263 Australia (May, 2012). Photo: Thomas Baumgartl.

264 **Figure 2.** Quarry mine restoration using woodchip mulch and compost as soil amendments
265 (green square-shaped patch in the lower side of the photo) in South Spain (Jun 2016). Photo:
266 Albert Sole.

267 **Figure 3.** Soil substrates from degraded arid soils with loamy sand texture inoculated with
268 cyanobacteria isolated from soil biocrust. Microcosms next to the flasks with cyanobacteria
269 cultures contain inoculated soils (three replicates). The other microcosms contain non-
270 inoculated soils (Sep 2018). Photo: Jose Raul Roman.