32. Restoration of degraded grassland

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1. Description of the practice

Grassland degradation is a complex concept that encompasses several aspects that relate to changes compared to a reference state. These include alterations in soil conditions, biodiversity, productivity, and socio-economic implications, and can differ at various degradation stages (Andrade *et al.*, 2015). Degradation may be the result of changes of two main types of properties: biotic and abiotic (Andrade *et al.*, 2015). Biotic changes include biodiversity alteration, species composition, and basic ecological functions such as for example pollination deviations, and these can be the consequence of land use change, overgrazing and alien species introduction. Regarding abiotic factors contributing to degradation, changes in soil chemical and physical properties are comprised mostly due to fertilization and/or soil cultivation malpractice. Additionally, degraded unmanaged grasslands in tropical regions lose carbon (C) from the system due to animal trampling (Hiltbrunner *et al.*, 2012) that form bare steps and vegetated shoulders occurring in between the steps. Similarly, C losses occur from grasslands in Brazilian Rondônia and Mato Grosso due to burning every 5-10 years to control weeds and woody plants (Maia *et al.*, 2009). Other direct human causes of degradation for example are soil cultivation, infrastructure construction, and pollution.

The starting point for restoration is to look at the degree of degradation and find a traditional system with autochthone species (native/pristine), with high biodiversity and under extensive management including grazing exclusions. Among restoration strategies, considering the local hotspot of native species nearby, a self-recovery allowing re-invasion of those species in the degraded grassland may be applicable in some mild situations, or in regions lacking available techniques. Nevertheless, it is important to evaluate at what point a recovery without additional technical measures is possible. Conversely, technical assistance may be needed in more serious situations (e.g. modification of soil features, control of undesired species, and introduction of desired species). One measure is usually not enough but any change in grassland management will impact on soil properties (Andrade *et al.*, 2015).

Grassland restoration includes actions for biotic and abiotic improvement measures for example: (i) introduction of autochthone species, (ii) elimination of invasive species, (iii) controlled fertilisation, (iv) irrigation, (v) reseeding, (vi) cutting grass, (ix) topsoil transplantation, (xi) fencing, (xii) implementation of better grazing systems, (xiii) erosion control, and (xiv) green ecological barriers (Zhou, Lee and Yue, 2020). Regardless of the measure(s) adopted, the first action is to eliminate the source of the existing pressure on the grassland.

2. Range of applicability

These practices are applicable worldwide for a wide range of pedo-climatic conditions, wherever there is a degraded grassland. The cause of degradation and the extent to which it affects the grassland are to be taken into consideration when planning the restoration. Tropical and sub-tropical areas are particularly sensitive to degradation, mainly due to land use change, and inappropriate livestock grazing. This also caused rapid and abrupt changes in social structure, cultural habits, and patterns of land ownership.

3. Impact on soil organic carbon stocks

The common impact of degraded grassland on SOC is loss of SOC rather than sequestration. For example, animal trampling on a sub-alpine pasture site used for over 150 years for summer grazing in Switzerland caused 30 percent higher SOC loss from bare shoulder than the vegetated shoulder (Hiltbrunner *et al.*, 2012).

Appropriate management to restore the degraded and abandoned grasslands may significantly increase C sequestration rates (Table 139).

Table 139. Evolution of Soc stocks after restoration of degraded grassland

Location	Climate zone	Soil type (Depth)	Additional C storage (tC/ha/yr)	Duration (year)	More information	Reference
Rondônia and Mato Grosso, Brazil	Humid tropics	Oxisols (0-25 cm)	(-) 0.27-0.28	5-10	Degraded grassland	Maia *et al.* (2009)
Minnesota, United States of America	Humid continental	Glacial outwash sandplain (0-30 cm)	0.08 - 0.71	22	Managed grassland (i.e. grazing, fertilisation)	Yang *et al.* (2019)
Canada	Temperate	NA	0.02-1.00	NA	Restore permanent grass	Hutchinso, Campbell and Desjardins (2007)

4. Other benefits of the practice

4.1. Improvement of soil properties

Developing actions to restore biodiversity in the long-term increases soil C and N storage (De Deyn *et al.* 2010). These are associated with the high rates of C and N accumulation and improvement of soil structure at a reduced ecosystem respiration rate. It could be further beneficial when restoration includes the increased abundance of at least one legume species in the grassland. Adequate management practices, as described above, deliver additional ecosystem benefits such as N storage in soil and improved soil structure (De Deyn *et al.*, 2010).

4.2. Minimization of threats to soil functions

Table 140. Soil threats

Soil threats	
Soil erosion	Restoring a grassland implies the improvement of soil quality, and thereby control of erosion.
Nutrient imbalance and cycles	Improves nutrients cycles.
Soil salinization and alkalinisation	May also be the reasons for degradation but difficult to restore.
Soil contamination / pollution	Contaminants/pollutants could be eliminated or reduced.
Soil acidification	Reclamation of soil acidity may be feasible by means of liming.
Soil biodiversity loss	Will improve soil biodiversity.
Soil compaction	Increase in soil C and that can help reduce compaction.
Soil water management	Improved soil structure can increase water use efficiency.

4.3. Increases in production (e.g. food/fuel/feed/timber/fibre)

Restored grasslands will produce more and better pasture and silage to feed livestock.

4.4. Mitigation of and adaptation to climate change

In addition to improve soil quality and reduce soil C loss, restored grassland could offset N_2O and CH_4 emissions through C sequestration while adapting to changing climatic condition.

4.5. Socio-economic benefits

In developing areas, grasslands are a major source of income through small farming activity and pastoralism. Therefore, grasslands restoration could have positive impacts on earning for farming communities and businesses. There is a strong relation between grassland-based livestock production and food security (Wilkes, Solymosi and Tennigkeit, 2012). Within this socio-economic context, improved grassland or pasture management can combat the risk of land degradation and help restore degraded sites leading to a better plant and litter cover, less vulnerability to erosion, less soil compaction and a higher biodiversity.

4.6. Other benefits

Landscape aesthetic benefits contribute to the wellbeing of people and facilitate tourism activities. Mixed production systems to meet up additional feed supplement for livestock products and proper use of resources to maintain biodiversity while decreasing C losses could be beneficial to prevent grassland degradation.

5. Potential drawbacks to the practice

5.1. Tradeoffs with other threats to soil functions

Table 141. Soil threats

Soil threats	
Soil salinization and alkalinisation	Limited or none.
Soil contamination / pollution	Limited or none except fertilizer-induced contaminants.
Soil acidification	Limited or none.
Soil compaction	Limited except trampling through grazing.

5.2. Increases in greenhouse gas emissions

Although restoration of degraded grasslands increases soil C sequestration, reductions in GHGs may not always be the best indicator to evaluate improved environmental and development outcomes in grasslands (Wilkes, Solymosi and Tennigkeit, 2012). In degraded arid and semi-arid grasslands, for example, GHG emissions may be less responsive to changes in pasture and silage management than to climate variability. There are restoration practices (e.g. revegetation, grazing fallow and grassland fencing) applicable for the lightly to severely degraded grasslands. In addition to adaptive strategies, rotational grazing with moderate intensity could retain or enhance soil fertility, plant growth, carbon and nitrogen storage while reducing GHG emissions (Dong *et al.*, 2020). Despite large potential for GHG mitigation in grasslands, uncertainty prevails for the implementation of good management practices. However, co-benefits of C sequestration and estimated emission reductions can be sufficiently attractive from an economic point of view.

5.3. Conflict with other practice(s)

Urbanization is a major conflicting activity for the restoration of degraded grasslands. as other activities may be prioritized in urban areas.

5.4. Other conflicts

Land ownership and funding could limit the restoration of degraded grasslands.

6. Recommendations before implementing the practice

A degraded site always needs earlier evaluation to assess the need for intervention, compared to the natural recovery capacity of the grassland. Degradation intensity and origin analysis will inform the necessary measures to implement the restoration techniques. According to Phillips-Mao (2017), this process typically includes several basic steps for example: (i) the assessment of the site to identify its characteristics and define the needs and goals for the restoration, (ii) vegetation removal to eliminate weeds and undesired vegetation that may out-compete with native species; (iii) preparation of the seed bed to ensure good seed-soil contact and promote germination, and (iv) seeding/planting of the select seed mixtures. Additionally, minimization of environmental impacts and measures to maintain or increase biodiversity are highly desirable. To avoid further land degradation, better management practices including optimal seasonal grazing, reseeding and provision of incentives and restrictions (grazing bans and reduction in livestock density) to improve grassland conditions should be adopted, depending on socio-economic and cultural conditions.

7. Potential barriers for adoption

Table 142. Potential barriers to adoption

Barrier	YES/NO	
Social	Yes	Degraded grasslands in underdeveloped regions may be linked to social issues.
Economic	Yes	Restoration process may be costly.
Legal (Right to soil)	Yes	Depending on land ownership.
Knowledge	Yes	Restoration practice is a long-term process and knowledge is still limited.

Photos of the practice

Photo 41. Showing degraded (left) and restored (Right) grasslands (Source: DOI: 10.5194/bgd-11-5613-2014).

Table 143.Related cases studies available in volumes 3 and 5

Title	Region	Duration of study (Years)	Volume	Case-study No.
Integrated farming in tropical agroecosystems of Brazil	Latin America and the Caribbean	4 to 12	3	34

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