RESTORATION ECOLOGY
The Journal of the Society for Ecological Restoration
SER SOCIETY FOR ECOLOGICAL RESTORATION

STRATEGIC ISSUES ARTICLE

Grasslands and savannahs in the UN Decade on Ecosystem Restoration

Nigel Dudley[1,2], Luca Eufemia[3], Martina Fleckenstein[4], Maria E. Periago[5], Ilka Petersen[4], Jean F. Timmers[6]

Grasslands and savannahs are suffering heavy losses from degradation and conversion. The UN Decade on Ecosystem Restoration offers important opportunities to address these losses through a range of restoration techniques. However, if poorly planned, the Decade could undermine some remaining natural and semi-natural grassland and savannah ecosystems by encouraging afforestation on these areas, thus acting as a perverse incentive. This article outlines the main issues and steps needed to ensure that the Decade creates positive outcomes for these important and highly biodiverse ecosystems: (1) better understanding of status and trends in degraded and converted grasslands and savannahs; (2) making the case for grassland and savannah restoration at both national and international levels; (3) ensuring post-2020 biodiversity conservation targets address all natural ecosystems; (4) improving selection tools for restoration to avoid displacing valuable ecosystems; and (5) identifying successful grassland and savannah restoration approaches that address ecological, cultural, and social needs.

Key words: grassland, restoration, savannah, UN Decade on Restoration

Implications for Practice

- Grassland and savannah restoration should become a key component of the UN Decade on Restoration.
- To facilitate this, urgent research is needed both to identify global hotspots of important natural and semi-natural grasslands and savannahs and to find tailored restoration approaches for these places.
- To avoid perverse results, forest restoration programs require planning to ensure that they are not displacing natural, old-growth or any ecologically important semi-natural grasslands and savannahs.

Introduction

Efforts to halt environmental damage have so far proved partially successful but key ecosystems continue to be destroyed or degraded (UNCCD 2017). In some cases, such as tropical forests, losses have even accelerated in recent years (Weisse & Dow Goldman 2019). Taking a proactive approach, the United Nations will support a "Decade on Ecosystem Restoration" from 2021 to 2030 in an attempt to restore lost ecosystem services and stem the rapid decline of biodiversity (UNEP & FAO 2020). Much of the emphasis of publicity surrounding the Decade has been on restoration of degraded or converted forests (linked especially to the Bonn Challenge, Stanturf et al. 2019; Holl & Brancalion 2020), but the Decade is aimed at all kinds of ecosystem restoration (UNEP & FAO 2020). Grasslands and savannahs cover around a one-third of the land surface (Bond 2019) and are as urgently in need of restoration effort as other ecosystems (Buisson et al. 2018) but are in danger of being forgotten or taking second place.

The Decade creates both opportunities and risks. Critics point out that the lack of knowledge about many aspects of restoration and the frequency of failed restoration projects show problems in implementation (Cooke et al. 2019). Others are more optimistic, stressing the opportunities to develop more considered and successful restoration (Young & Schwartz 2019). We argue that there are clear opportunities to make the case for restoration of degraded or converted grasslands and savannahs within the Decade, with both ecological and socio-economic incentives, and thus to use this period as a way to help build knowledge, capacity, and funding for restoration of these ecosystems. But there are also some risks, in particular, that heavy-handed or poorly planned efforts to restore forests might have the perverse result of establishing forests over important natural or semi-natural grassland and savannah ecosystems. This article outlines the implications for grasslands and savannahs and suggests some urgent actions needed to ensure that they benefit from the push toward greater restoration during the Decade to ensure that it results in positive outcomes for these ecosystems.

Author contributions: all authors contributed to the thinking outlined in the article; ND wrote the initial manuscript and all authors modified and agreed the final text.

[1]Equilibrium Research, 47, The Quays, Cumberland Road, Bristol, BS1 6UQ, U.K.
[2]Address correspondence to N. Dudley, email nigel@equilibriumresearch.com
[3]Leibniz Centre for Agricultural Landscape Research (ZALF), 84, Eberswalder Street, Müncheberg, 15374, Germany
[4]WWF, 18, Reinhardt Street, Berlin, 10117, Germany
[5]Fundación Vida Silvestre Argentina, Defensa 251 6K, Buenos Aires, 1065, Argentina
[6]WWF Brazil, CLS 114 Bloco D - Asa Sul, Brasília, 70377-540, Brazil

doi: 10.1111/rec.13272

The Challenge in Degradation and Loss in Grassland and Savannah Ecosystems

There have been few global studies on the status of grassland and savannah ecosystems. Indeed, there is continuing debate about the definition of a savannah and at exactly when there is a transition between savannah and open woodland (see debate in Dixon et al. 2014). It is 20 years since the World Resources Institute produced their overview of global grasslands (White et al. 2000), almost as long since High Conservation Value Grasslands were identified for southern South America (Bilenca & Miñarro 2004), and 6 years since WWF and partners pulled together a global map of grasslands (Dixon et al. 2014). Since then, additional areas of natural grassland have been recognized, for instance, in Madagascar (Vorontosva 2016), eastern North America (Noss et al. 2015), and eastern Europe (Feurdean et al. 2015), and an updated and expanded survey is overdue.

More recently, the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services estimated that land degradation has reduced the productivity of 23% of the global land surface, much of this on grassland ecosystems (IPBES 2019). Similarly, the *Global Land Outlook* from the UNCCD estimated that 1.3 billion people live on degrading agricultural land (UNCCD 2017). In addition, grasslands and savannahs face many additional conservation challenges, from degradation and loss, which impact ecosystems as a whole and the individual species that inhabit them (Table 1).

No global figures exist for degradation or conversion of grasslands and savannahs, and statistics for the establishment of crops such as soya and palm oil tend to focus on tropical forests, while the conversion of grasslands such as the pampas grasslands is overlooked. Nevertheless, there are good current monitoring data available on some of the areas with the highest global levels of grassland and savannah conversion being caused by soft commodities expansion, for instance in the South American Cerrado (Terrabrasilis 2016–2020) and the North American Great Plains (WWF 2018). Similar overview information is still lacking for new emerging frontiers, such as in the Asian steppes and sub-Saharan savannahs, although in the latter there is evidence of savannah loss from crop conversion (Andela & Van Der Werf 2014) and, in Central Africa, from forest expansion in the twentieth century (Aleman et al. 2018).

Furthermore, it is sometimes difficult to determine what the restoration objectives should be in long-managed grassland and savannah ecosystems, although this is changing. Concepts of naturalness in grasslands and savannahs are emerging from recent studies (Ratnam et al. 2011), indicating that these are mostly ancient ecosystems, with adaptations to natural fire and grazing developed over millions of years (Veldman et al. 2015; Karp et al. 2018; Feurdean & Vasiliev 2019). Many herbivores, their predators, and our own species emerged from this long history (Cerling et al. 2011; Levin 2015). Therefore, grasslands and savannahs face two challenges: first, outright conversion to crops, plantation forests or urban development and, second, a level of intensification that destroys many of the natural values (Gossner et al. 2016). Degradation and loss have major impacts on a wide range of ecosystem services, including carbon storage, water security, soil stabilization, and biodiversity (Wen et al. 2013).

Table 1. A simplified range of impacts on grasslands and savannahs.

Impacts	*Details and Examples*
Degradation	
Simplification	Loss of key species due to over- and under-grazing, alien and invasive species, agrochemical use, air pollution, etc.
Partial loss of vegetation cover	Through over-grazing, compaction by heavy machinery, pesticide misuse, climate change
Total loss of vegetation cover – leading to desertification	Through persistent over-grazing, vehicle use, large-scale pollution
Conversion	
Alien grasses	Replacement of natural species with monocultures of non-native, high productive species for grazing, golf courses, etc.
Woody encroachment	Can be caused by overgrazing that represses grass fires, or as a result of climate change
Crops	Replacement with mixed agriculture or with monoculture crops such as soya, palm oil, corn, wheat, cotton, etc.
Trees	Planting of non-native, fast-growing species such as *Eucalyptus*, *Acacia,* or some conifers
Infrastructure	Replacement by roads, rail links, airports, urban areas, industrial complexes, etc.

The Particular Challenge of Forest Restoration Replacing Grasslands and Savannahs

Efforts to conserve forests have not infrequently resulted in displacement of activities into grasslands and savannahs, classically in the case of the Brazilian Cerrado, which has suffered partially in consequence of efforts to protect the Amazon (Brannstrom 2009). The same effect occurs in China (Cao 2008) and in new frontiers such as Congo Basin (Ickowitz et al. 2015), displacing pressure onto regional savannahs. Degraded grasslands and savannahs are sometimes planted with commercial trees or restored as "natural" forests, and natural grasslands are sometimes mistaken for degraded forests (Veldman 2016) with the same results. These perverse results could continue in the Decade on Ecosystem Restoration, if narrowly focused forest "restoration" takes place in natural, old-growth grasslands (Fernandes et al. 2016) or savannahs (Bond 2016), or more locally on semi-natural ecosystems that have important associated flora and fauna (Valkó et al. 2016). The drive to sequester carbon through forest restoration could

intensify these problems (Bastin et al. 2019). The political momentum behind the Bonn Challenge is persuading governments to set ambitious targets without necessarily having the space on which to plant. Identification of areas suitable for reforestation, for example by the World Resources Institute (2014), has been criticized as including important natural grassland areas (Veldman et al. 2015a), although attempts to integrate multiple factors into forest restoration site selection are becoming available (Brancalion et al. 2019).

Restoration Potential

We know that grasslands and savannahs can be restored, even in conditions where they are highly degraded (Blakesley & Buckley 2016; Waldén & Lindborg 2016). There can be challenges in restoring tropical and subtropical grasslands after afforestation (e.g. Zaloumis & Bond 2016; Buisson et al. 2018), and throughout the world, climate change means that restoration will not always recreate a replica of the ecosystem before degradation and must necessarily be informed by both native reference ecosystems and by actual or projected environmental change (Harris et al. 2006; Gann et al. 2019). Furthermore, increased climate variability will bring new challenges to restoration in many places, increasing the need for adaptive approaches (Falk & Millar 2016). Simple and affordable methods may involve removing pressures and allowing natural recovery (Wang et al. 2017) or improving fire management (Lipsett-Moore et al. 2018), including anthropogenic fire use (e.g. Davis & Miller 2018), and grazing (Manning et al. 2017) management, including pastoralism (Galvin 2009), frequently using knowledge from traditional and indigenous communities (Selemani et al. 2012). Direct seedling (Bissett 2006; Sampaio et al. 2019), enhancement planting (Slodowicz et al. 2019), and, in arid areas, the use of irrigation are all employed to speed up the process and to replace species that have disappeared from the seed pool. The interplay between the use and timing of managed grazing and grazing exclusion in grassland restoration is still being worked out in many ecosystems (e.g. Xiong et al. 2016). Spectacular examples of grassland and savannah (Pellizzaro et al. 2017) restoration have been achieved in a few years and there are real opportunities to see positive results during the period of the Decade on Ecosystem Restoration, which may itself encourage governments to take part.

For the purpose of climate change mitigation, restoring grasslands and savannahs represents a huge and widely overlooked potential. A conservative calculation estimated the total carbon stored by grasslands and savannahs at 470 Gt (i.e. one-fifth of the total carbon contained in terrestrial vegetation and topsoil worldwide), an average of 150–200 tons of carbon per hectare (Epple et al. 2016). Restoring grasslands and savannahs facilitates carbon sequestration from the atmosphere relatively quickly and resiliently (Dass et al. 2018), as most of the carbon is stored underground and protected from droughts and wildfires. Restoration of late-stage successional grasslands speeds up the rate of soil carbon accumulation (Yang et al. 2019).

Next Steps in Preparing for the Decade on Ecosystem Restoration

Making sure that the Decade produces positive results for grasslands and savannahs requires some work. While this global effort has the potential to foster public awareness about the importance of having functional ecosystems to ensure human well-being and sustainable development, a deeper understanding of critical grasslands and savannahs can champion novel and innovative tools for restoration. In the same way, a greater active involvement from key stakeholders, including governmental bodies at all scales, local and indigenous communities, NGOs, academics, and people with expertise in environmental issues and human rights, could pave the way to design and develop activities and initiatives that are climate friendly, conservation driven, and cost-effective.

Below we identify five steps that should be taken in the short term.

(1) *Develop a better understanding of status and trends in remaining natural grasslands and savannahs*: We still know comparatively little about rate of loss, levels of threat, and the location of many degraded grassland and savannah ecosystems. Information exists but has yet to be assembled and analyzed, other data are still lacking. There is an urgent need to pull together what we know to provide an overall picture of the status of and threats to grassland and savannah with emphasis on hotspots of loss and conservation priorities.

(2) *Making the case for restoration*: A series of publications and initiatives will be needed to ensure that grassland and savannah restoration is addressed in the Decade. Some are already underway, such as a Grassland and Savannah initiative being launched by WWF International. Issues to focus on involve ecosystem services, including particularly the role of grassland and savannah in providing secure carbon storage, food security, and other social, cultural, and conservation needs. It may be worth exploring a high-level call for action from prominent conservationists to build momentum.

(3) *Ensuring post-2020 targets address all the world's natural ecosystems*: Grassland and savannah conservation needs the global attention given to forests, from the perspective of area-based conservation, sustainable management, and ecological restoration. This includes increasing coverage of protected and conserved areas, particularly in ecosystems where losses are accelerating, implementing policies and incentives for increasing the uptake of certification schemes for sustainable management at scale and building greater expertise in restoration, using both science and traditional knowledge. Current debates in the Convention on Biological Diversity and UN Framework Convention on Climate Change are important. Governmental and private sector targets to reduce or eliminate deforestation need to address more general loss or conversion of any natural ecosystems. Proposed measures of terrestrial conservation success based narrowly around changes in forest cover should be modified to consider all the natural terrestrial habitats, in order to avoid perverse results. Targets to reduce or eliminate

grassland and savannah conversion and degradation should be set.

(4) *Improving selection tools for restoration*: Planning tools for forest restoration need to give effective weight to what is being replaced. This is currently not always the case. Working with partners will be important, for instance in the FAO Forest and Landscape Restoration Initiative. Key steps here will be to ensure that restoration addresses all ecosystems equally, that tree restoration and tree plantation incentives respect all types of natural ecosystem, and that the trade-offs between different restoration strategies are assessed to ensure optimal results at a landscape level.

(5) *Identifying and mainstreaming successful grassland and savannah restoration approaches*: Most grassland research focuses on agricultural systems; there is no journal of natural grassland research, few professional organizations, and a lack of easily accessible information. There is, however, a lot of practical experience and a pool of quickly vanishing traditional knowledge. Drawing together rangeland specialists, conservation biologists, restoration practitioners, and relevant people living in grasslands and savannahs to learn more about and provide guidance on successful approaches to grassland and savannah restoration, accessing both scientific research and traditional ecological knowledge, with case studies, at the start of the Decade on Ecosystem Restoration, would be a valuable contribution.

There is still much to be learned about the specific dynamic of grasslands and savannahs, their history, their soil microbiota, the long-term role of fire and of grazing in their evolution and restoration, the potential of grassland and savannah to serve as a carbon sequestration pool, the interplay between pastoralists and grassland ecosystems, and so on. Building a stronger and widely shared knowledge base about restoration of grassland and savannah could be one of the longer-term aims of the Decade, along with ensuring the existence of many restored ecosystems around the world.

Acknowledgments

We thank WWF International and the Sulu project for sponsoring this study as well as the participants in a workshop run by WWF Germany in July 2019 for their contributions to planning conservation responses in grasslands and savannahs. Sulu is part of the International Climate Initiative, supported by the Federal Ministry for the Environment, Nature Conservation and Nuclear Safety (BMU) on the basis of a decision adopted by the German Bundestag. We also thank W. J. Bond, three anonymous reviewers, and the managing editor for detailed comments on earlier drafts.

LITERATURE CITED

Aleman JC, Jarzyna MA, Staver AC (2018) Forest extent and deforestation in tropical Africa since 1900. Nature Ecology and Evolution 2:26–33

Andela N, Van Der Werf GR (2014) Recent trends in African fires driven by cropland expansion and El Niño to La Niña. Nature Climate Change 4:791–795

Bastin JF, Finegold Y, Garcia C, Mollicone D, Rezende M, Routh D, Zohner CM, Crowther TW (2019) The global tree restoration potential. Science 365: 76–79

Bilenca D, Miñarro F (2004) Identificación de Áreas Valiosas de Pastizal en las pampas y campos de Argentina, Uruguay y Sue de Brasil. JM Kaplan Fund and Fundación Vida Silvestre, Buenos Aires

Bissett NJ (2006) Restoration of dry prairie by direct seeding: methods and examples. Pages 231–237. In: Ross RF (ed) *Land of fire and water*: the Florida dry prairie ecosystem. Proceedings of the Florida Dry Prairie Conference Sebring, Florida

Blakesley D, Buckley P (eds) (2016) Grassland restoration and management. Pelagic Publishing, Exeter, United Kingdom

Bond WJ (2016) Ancient grasslands at risk. Science 351:120–122

Bond WJ (2019) Open ecosystems: ecology and evolution beyond the forest edge. Oxford, England: Oxford University Press

Brancalion PHS, Niamir A, Broadbent E, Crouzeilles R, Barros FSM, Almeyda Zambrano AM, et al. (2019) Global restoration opportunities in tropical rainforest landscapes. Science Advances 5:eaav3223

Brannstrom C (2009) South America's neoliberal agricultural frontiers: places of environmental sacrifice or conservation opportunity? Ambio 38:141–149

Buisson E, Le Stradic A, Silveira FAO, Durigan G, Overbeck GE, Fidelis A, et al. (2018) Resilience and restoration of tropical and subtropical grasslands, savannas and grassy woodlands. Biological Reviews 94:590–609

Cao S (2008) Why large-scale afforestation efforts in China have failed to solve the desertification problem. Environmental Science and Technology 15: 1826–1831

Cerling TE, Wynn JG, Andanje SA, Bird MI, Kimutai Korir D, Levin Naomi E, Mace William, Macharia Anthony N, Quade Jay, Remien Christopher H (2011) Woody cover and hominin environments in the past 6 million years. Nature 476:51–56

Cooke SJ, Bennett JR, Jones HP (2019) We have a long way to go if we want to realize the promise of the "Decade on Ecosystem Restoration". Conservation Science and Practice 1:e129

Dass P, Houlton BZ, Wang Y, Warlind D (2018) Grasslands may be more reliable carbon sinks than forests in California. Environmental Research Letters 13: 074027

Davis MA, Miller A (2018) Savanna restoration using fire benefits birds utilizing dead trees, up to a point. The American Midland Naturalist 179: 94–104

Dixon AP, Faber-Langendoen D, Josse C, Morrison J, Loucks CJ (2014) Distribution mapping of world grassland types. Journal of Biogeography 41: 2003–2019

Epple C, García Rangel S, Jenkins M, Guth M (2016) *Managing ecosystems in the context of climate change mitigation: a review of current knowledge and recommendations to support ecosystem-based mitigation actions that look beyond terrestrial forests*. Technical Series No. 86. Secretariat of the Convention on Biological Diversity, Montreal

Falk DA, Millar CI (2016) The influence of climate variability and change on the science and practice of restoration ecology. In: Palmer MA, Zedler JB, Falk DA (eds) Foundations of restoration ecology. Island Press, Washington D.C.; Covelo, California; London, United Kingdom

Fernandes GW, Serra Cielho M, Bomfin Machado R, Ferreira ME, Moura de Souza Aguiar L, Dirzo R, Scariot A, Lopes CR (2016) Afforestation of savannas: an impending ecological disaster. Natureza and Conservação 14:146–151

Feurdean A, Vasiliev I (2019) The contribution of fire to the late Miocene spread of grasslands in eastern Eurasia (Black Sea region). Scientific Reports 9:1–7

Feurdean A, Marinova E, Nielsen AB, Liakka J, Veres D, Hutchinson SM, et al. (2015) Origin of the forest steppe and exceptional grassland diversity in Transylvania (central-eastern Europe). Journal of Biogeography 42: 951–963

Galvin KA (2009) Transitions: pastoralists living with change. Annual Review of Anthropology 38:185–198

Gann GD, McDonald T, Walder B, Aronson J, Nelson CR, Jonson J, et al. (2019) International principles and standards for the practices of ecological restoration. Second edition. Restoration Ecology 27:S1–S46

Gossner MM, Lewinsohn TM, Kahl T, Grassein F, Boch S, Prati D, et al. (2016) Land-use intensification causes multitrophic homogenization of grassland communities. Nature 540:266–269

Harris JA, Hobbs RJ, Higgs E, Aronson J (2006) Ecological restoration and global climate change. Restoration Ecology 14:170–176

Holl KD, Brancalion PHS (2020) Tree planting is not a simple solution. Science 368:580–581

Ickowitz A, Slayback D, Asanzi P, Nasi R (2015) Agriculture and deforestation in the Democratic Republic of the Congo: a synthesis of the current state of knowledge. Occasional Paper 119. Center for International Forestry Research, Bogor, Indonesia

IPBES (2019) Summary for policymakers of the global assessment report on biodiversity and ecosystem services of the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services. IPBES Secretariat, Bonn, Germany

Karp AT, Behrensmeyer AK, Freeman KH (2018) Grassland fire ecology has roots in the late Miocene. Proceedings of the National Academy of Sciences 115:12130–12135

Levin NE (2015) Environment and climate of early human evolution. Annual Review of Earth and Planetary Sciences 43:405–429

Lipsett-Moore GJ, Wolff NH, Game ET (2018) Emission mitigation opportunities for savanna countries from early dry season fire management. Nature Communications 9:2247

Manning GC, Baer SG, Blair JM (2017) Effects of grazing and fire frequency on floristic quality and its relationship to indicators of soil quality in tallgrass prairie. Environmental Management 60:1062–1075

Noss R, Platt WJ, Sorrie BA, Weakley AJ, Means BD, Costanza Jennifer, Peet Robert K (2015) How global biodiversity hotspots may go unrecognized: lessons from the North America coastal plain. Diversity and Distributions 21:236–244

Pellizzaro KF, Cordeiro AOO, Alves M, Motta CP, Rezende GM, Silva RRP, Ribeiro JF, Sampaio AB, Vieira DLM, Schmidt IB (2017) "Cerrado" restoration by direct seeding: field establishment and initial growth of 75 trees, shrubs and grass species. Brazilian Journal of Botany 40:681–693

Ratnam J, Bond WJ, Fensham RJ, Hoffmann WA, Archibald S, Lehmann CER, et al. (2011) When is a 'forest' a savanna, and when does it matter? Global Ecology and Biogeography 20:653–660

Sampaio AB, Vieira DLM, Holl KD, Pellizzaro KF, Alves M, Coutinho AG, Cordeiro A, Ribeiro JF, Schmidt IB (2019) Lessons on direct seeding to restore Neotropical savannah. Ecological Engineering 138:148–154

Selemani IS, Eiko LO, Holland O, Ådnøy T, Mengisi E, Mushi D (2012) The role of indigenous knowledge and perceptions of pastoral communities on traditional grazing management in north-western Tanzania. African Journal of Agricultural Research 7:5537–5547

Slodowicz D, Humbert YV, Arlettaz R (2019) The relative effectiveness of seed addition methods for restoring or re-creating species rich grasslands: a systematic review protocol. Environmental Evidence 8:28

Stanturf JA, Kleine M, Mansourian S, Parrota J, Madsen P, Kant Promode, Burns Janice, Bolte Andreas (2019) Implementing forest landscape restoration under the Bonn Challenge: a systematic approach. Annals of Forest Science 76:50

Terrabrasilis (2016–2020) http://terrabrasilis.dpi.inpe.br/en/home-page/ (accessed 26 Apr 2020)

UNCCD (2017) Pages 64–65. Global land outlook. UN Convention to Combat Desertification, Bonn, Germany

UNEP and FAO (2020) Strategy of the UN Decade on Ecosystem Restoration. Nairobi and Rome. Draft 6 February 2020

Valkó O, Zmiorski M, Biurrun I, Loos J, Labadessa R, Venn S (2016) Ecology and conservation of steppes and semi-natural grasslands. Hacquetia 12:5–15

Veldman JW (2016) Clarifying the confusion: old-growth savannahs and tropical ecosystem degradation. Philosophical Transactions of the Royal Society B 371:20150306

Veldman JW, Buisson E, Durigan G, Wison Fernandes G, Le Stradic S, Mahy G, et al. (2015) Towards an old-growth concept for grasslands, savannas, and woodlands. Frontiers in Ecology and the Environment 13:154–162

Veldman JW, Overbeck GE, Negreiros D, Mahy G, Le Stradic S, Fernandes GW, Durigan G, Buisson E, Putz FE, Bond WJ (2015a) Tyranny of trees in grassy biomes. Science 347:484–485

Vorontosva M (2016) Madagascar's grasses and grasslands: anthropogenic or natural? Proceedings of the Royal Society B 283:20152262

Waldén E, Lindborg R (2016) Long-term positive effect of grassland restoration on plant diversity – success or not? PLoS One 11:e0155836

Wang L, Gan Y, Wiesmeier M, Zhao G, Zhang R, Han G, Siddique KHM, Hou F (2017) Grazing exclusion: an effective approach for naturally restoring grasslands in Northern China. Land Degradation and Development 29: 4439–4456

Weisse M, Dow Goldman E (2019) The world lost a Belgium-sized area of primary rainforests last year. World Resources Institute, 29th April 2019, https://www.wri.org/blog/2019/04/world-lost-belgium-sized-area-primary-rainforests-last-year (accessed 31 May 2019)

Wen L, Dong S, Li Y, Li X, Shi J, Wang Y, Liu D, Ma Y (2013) Effect of degradation intensity on grassland ecosystem services in the Alpine Region of Qinghai-Tibetan plateau, China. PLoS One 8:e58432

White RP, Murray S, Rohweder M (2000) Pilot analysis of global ecosystems: grassland ecosystems. World Resources Institute, Washington D.C.

World Resources Institute, 2014. Atlas of Forest and Landscape Restoration Opportunities. https://www.wri.org/resources/maps/atlas-forest-and-landscape-restoration-opportunities (accessed 25 Apr 2020)

WWF (2018) The Plowprint report 2018. WWF Northern Great Plains, Bozeman, Montana

Xiong D, Shi P, Zhang X, Zou CB (2016) Effects of grazing exclusion on carbon sequestration and plant diversity in grasslands in China – a meta-analysis. Ecological Engineering 94:647–655

Yang Y, Tilman D, Furey G, Lehman C (2019) Soil carbon sequestration accelerated by restoration of grassland biodiversity. Nature Communications 10:718

Young TP, Schwartz MW (2019) The Decade on Ecosystem Restoration is an impetus to get it right. Conservation Science and Practice 1:e145

Zaloumis NP, Bond WJ (2016) Reforestation or conservation? The attributes of old growth grasslands in South Africa. Philosophical Transactions of the Royal Society B 371:20150310

Coordinating Editor: James Aronson

Received: 6 May, 2020; First decision: 23 June, 2020; Revised: 19 August 2020 ; Accepted: 19 August, 2020