Biome Awareness Disparity is BAD for tropical ecosystem conservation and restoration

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Abstract

1. We introduce the concept of Biome Awareness Disparity (BAD)—defined as a failure to appreciate the significance of all biomes in conservation and restoration policy—and quantify disparities in (i) attention and interest, (ii) action, and (iii) knowledge amongst biomes in tropical restoration science, practice, and policy.

2. By analysing 50,000 tweets from all Partner Institutions of the UN Decade of Ecosystem Restoration, and 45,000 tweets from the main science and environmental news media worldwide, we found strong disparities in attention and interest relative to biome extent and diversity. Tweets largely focused on forests, whereas open biomes (such as grasslands, savannas, and shrublands) received less attention in relation to their area. In contrast to these differences in attention, there were equivalent likes and retweets between forest *vs*. open biomes, suggesting the disparities may not reflect the views of the general public.

3. Through a literature review, we found that restoration experiments are disproportionately concentrated in rain forests, dry forests and mangroves. More than half of the studies conducted in open biomes reported tree planting as the main restoration action, suggesting inappropriate application of forest-oriented techniques.

4. *Policy implications*. We urge scientists, policymakers and land managers to recognize the value of open biomes for protecting biodiversity, securing ecosystem services, mitigating climate change, and enhancing human livelihoods. Fixing Biome Awareness

Disparity will increase the likelihood of the United Nations Decade on Ecosystem Restoration successfully delivering its promises.

Key-words: afforestation, decolonisation, open ecosystems, savannas, reforestation, research bias, public perception, tree planting

Resumo

1. Nós introduzimos o conceito de disparidade de consciência de bioma (DCS)— definido como uma falha em reconhecer a importância de todos os biomas na política de conservação e restauração— e quantificamos disparidades em (i) atenção e interesse, (ii) ação, e (iii) conhecimento na ciência, prática e política de restauração de biomas tropicais.

2. Analisamos mais de 50,000 tweets de todas as instituições parceiras da Década das Nações Unidas para a Restauração de Ecossistemas, e mais de 45,000 tweets dos maiores canais de mídia de ciência e meio ambiente em todo mundo e encontramos fortes disparidades de atenção e interesse relativos à extensão e diversidade de biomas. Tweets focaram fortemente em florestas, enquanto biomas abertos (como campos, savanas e arbustais), receberam menor atenção relativo à sua área. Em contraste com as disparidades em atenção, encontramos um número equivalente de curtidas e retweets entre biomas florestais e biomas abertos, sugerindo que as disparidades não refletem a visão do público em geral.

3. Nossa revisão de literatura demonstrou que os experimentos de restauração se concentraram desproporcionalmente em florestas úmidas, secas e manguezais. Mais da metade dos estudos conduzidos em biomas abertos reportou o plantio de árvores como a

principal ação de restauração, sugerindo a aplicação incorreta de técnicas centradas em florestas.

4. Convidamos os cientistas, formuladores de políticas públicas e gestores ambientais a reconhecer o valor dos biomas abertos para proteção da biodiversidade, garantia de serviços ecossistêmicos, mitigação das mudanças climáticas, e melhoria dos meios de subsistência humana. Reparar a Disparidade de Consciência de Bioma aumentará a probabilidade de a Década das Nações Unidas para a Restauração de Ecossistemas cumprir com sucesso suas promessas.

Palavras-chave: florestamento, descolonisação, ecossistemas abertos, savanas, reflorestamento, viés de pesquisa, percepção pública, plantio de árvores

Introduction

The United Nations Decade on Ecosystem Restoration—a global call for the restoration of ecosystems—aims to protect biodiversity, secure ecosystem services, mitigate climate change, and enhance human livelihoods (https://www.decadeonrestoration.org/). To achieve these ambitious aims, scientists, policymakers, and land managers worldwide must overcome significant ecological and social challenges (Fleischmann et al., 2020, Holl & Brancalion, 2020). These challenges include: the ecological complexity and uniqueness of different biomes (Guerra et al., 2020, Strassburg et al., 2020); perceived biome biases in both science and restoration practice (Temperton et al., 2019); limited knowledge of restoration-relevant aspects of organismal biology and natural history (Ribeiro et al., 2016); socio-economic hurdles (Fischer et al., 2021); disputes as to what represents degradation in some ecosystems

(Vetter, 2020); and debates as to what policy and management interventions should qualify as restoration (Suding et al., 2015).

Despite the fact that all terrestrial biomes are experiencing human-induced environmental change, large-scale restoration initiatives primarily focus on forests and tree planting (Rominj et al., 2019). The tendency for restoration initiatives to assign greater value to forest and trees compared with open biomes (*sensu* Bond 2019)—characterised by a shade-intolerant understorey, including grasslands, savannas, open peatlands, heathlands, shrublands, and deserts— has its roots in 19th century European forestry traditions and persists today in postcolonial environmental governance beyond Europe (Davis & Robbins, 2018). Legacies of colonial environmental policies have been reinforced by European biases in the field of ecology that emphasized the role of climate, and deemphasized the roles of fire and herbivores, in determining the distribution of biomes (Pausas & Bond, 2019). As a consequence, ecosystems that are naturally maintained by fire and herbivores (e.g., savannas), and/or that occur in seasonally dry or semi-arid climates (e.g., shrublands), are widely misperceived as being degraded by human mismanagement (Fairhead & Leach, 1996).

Over recent decades these biases have contributed to a focus on tree planting to mitigate climate change through carbon sequestration (Martin et al., 2021). This focus on trees and carbon recently culminated in the assertion by Bastin et al. (2019) that tree planting could solve the climate crisis. Although this assertion, and the analyses on which it was based, have been thoroughly discredited (e.g., Bond et al. 2019, Friedlingstein et al., 2019; Lewis et al., 2019; Skidmore et al., 2019; Veldman et al., 2019), tree planting continues to be viewed by many policymakers and the public as a panacea (Holl & Brancalion, 2020). Such a view ignores the negative aspects of tree planting (Fleischman et al. 2020), including the disastrous consequences of afforestation

for open biomes that are not naturally dominated by trees and are characterised by a grassy understorey (Parr et al., 2014; Veldman et al., 2015): unlike tropical forests, open biomes are threatened not just by the loss of trees, but also by increases in tree cover (i.e., woody encroachment; Parr et al. 2014).

Amid the focus on forests and trees, there is a growing chorus of scientists working to demonstrate that many biomes, not just forests, have strong restoration potential for biodiversity, human livelihoods and climate mitigation (Temperton et al., 2019; Dudley et al., 2020). For the targets of the UN Decade on Ecosystem Restoration to be met, it is essential for restoration scientists, environmental policy makers and the public to recognize that an overemphasis on forests and trees will leave behind many ecosystems, along with the people who rely on them for their livelihoods.

Inspired by the framework of plant awareness disparity (i.e., the inattention to plants in one's own environment; Parsley, 2020), we introduce the concept of Biome Awareness Disparity (BAD). We define BAD as a failure to appreciate the significance of all biomes for conservation and restoration policy. We posit that BAD is a complex phenomenon that can be separated, and quantified, into three main components (modified from Parsley, 2020): (i) *Attention and Interest*, expressed as the differential representation of biomes by the scientific community, media and commercial interests; (ii) *Action*, assessed by comparing the number of restoration programs and initiatives across biomes; and (iii) *Knowledge*, reflected by the number of studies relating to ecosystem restoration within different biomes. Disparities are expressed relative to biome area rather than area to be restored. We focused our analysis on the tropical and subtropical regions of the global south because most areas targeted by global restoration initiatives are located at lower latitudes (Strassburg et al., 2020).

By quantifying the components of BAD, we demonstrate how disparities among biomes can jeopardize the goals of tropical restoration efforts. We then propose practical solutions to steer the policy and practice of ecosystem restoration toward success during the UN Decade on Ecosystem Restoration.

Materials Methods

To quantify the attention and interest components of BAD, in March 2021 we examined communication on restoration science, practice and policy on Twitter. We retrieved tweets using the R Package "rtweet" (Kearney, 2019) to obtain up to 3,200 original tweets—the limit imposed by the package functions—for each handle belonging to all Partner Institutions of the UN Decade on Ecosystem Restoration, which altogether have 12.3 million followers (Table S1). We recovered and examined 50,271 tweets from these collective handles. We also explored disparities in attention and interest in 45,392 tweets from the science and environmental news media worldwide, which included 18 Twitter handles from six countries and five languages. Collectively, these handles had 242 million followers (Table S2). To make our search as comprehensive as possible, we looked for tweets containing the words "restoration", "rehabilitation" or "revegetation", and included key terms that could help us associate each tweet with a biome *sensu* Olson et al. (2001) (Table S3). We were left with 940 and 18 tweets from Institutional and news media accounts, respectively (Silveira et al, 2021; Figure S1). Nearly 23% of these tweets were unambiguously related to (sub)tropical forests or another tropical biome, and another 45% related only to forest restoration or forest landscape restoration in general.

To explore disparities in action and knowledge, we ran a systematic literature review in Web of Science, searching for the combination of the terms "restoration

ecology" and tropic* in titles, abstracts and keywords of papers published between 1980 and January 2021. This search yielded 930 papers on tropical restoration. Of these papers, 367 met our criteria of being primary reports of field-based studies that were published in English. From these 376 papers, we extracted the geographic coordinates of the study location and recorded whether tree planting was used as a restoration technique. We plotted each study location onto the terrestrial biome classification map of Olson et al. (2001) and Dinerstein et al. (2017). We also assigned 99 review papers found in the literature search above to one or more of the following non-mutually exclusive categories: *Opportunities and Planning* (i.e., papers on theoretical frameworks, restoration policy, restoration targets and prioritization), *Restoration techniques* (e.g., natural regeneration, tree planting, seed sowing), *Monitoring* (i.e., ecological indicators and restoration outcomes), *Sustainability and resilience* (potential for natural regeneration, response to rapid environmental change), *Socioeconomy* (e.g., costs of restoration, value to human livelihoods), *Biodiversity* (ecology of species and communities, functional and phylogenetic diversity) and *Ecosystem services* (e.g., carbon storage, provisioning of water). We also recorded the biome or biomes addressed by each primary research study (n= 353) or review (n= 99) paper (Silveira et al., 2021).

Results

Disparities in attention and interest were demonstrated in tweets by the Partner Institutions of the UN Decade of Ecosystem Restoration, which largely focused on forests. Open biomes received far less attention in relation to their area ($\chi^2 = 864.75$, $p < 0.001$) (9.6 times more tweets for forests than for open biomes; Fig. 1A). However, we found no differences in the number of likes (Deviance= 2.72, p= 0.1; Fig. 1B) and retweets (Deviance= 3.42, p= 0.064; Fig. 2C) between forest and open biomes.

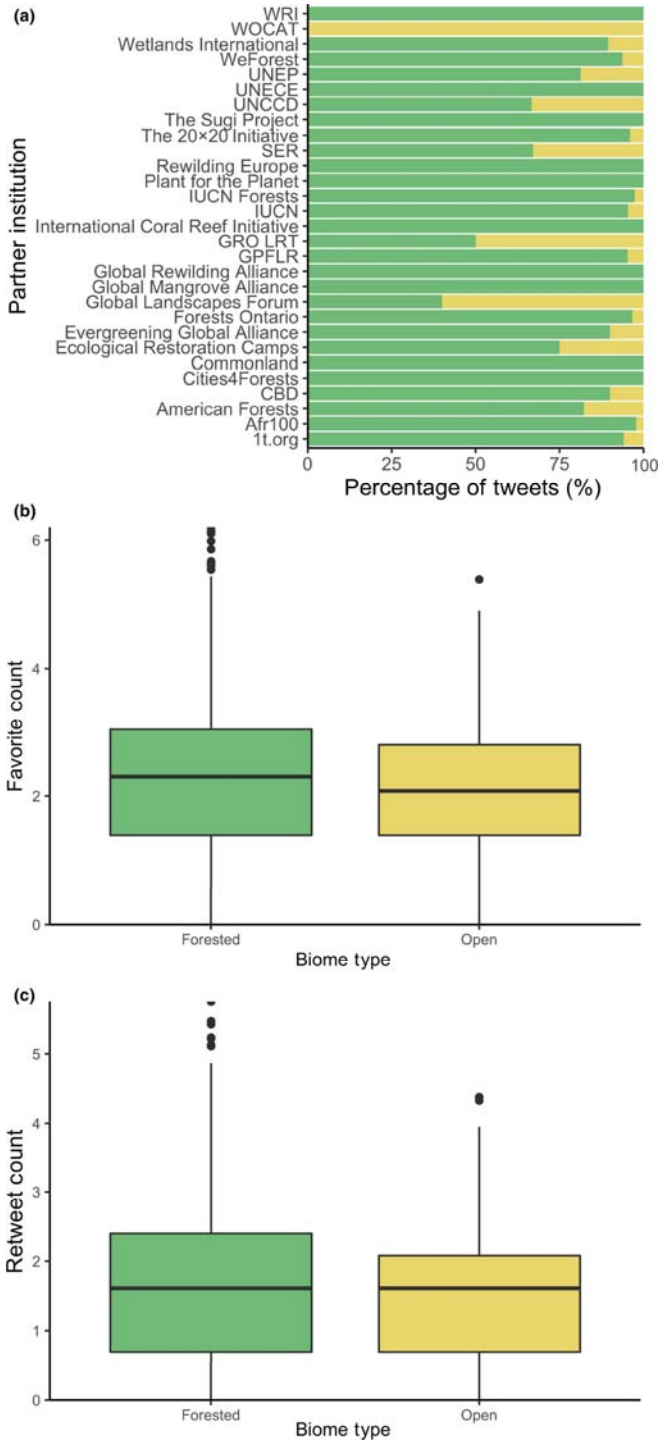

Figure 1. Awareness disparity in attention and interest across the world's biomes by all Partner Institutions of the UN Decade of Ecosystem Restoration represented by percentage of tweets (A). Average like counts (B), and average number of retweets (C) about forested (green) vs. open biomes (yellow). Boxplots represent the median (line), quartiles (boxes) and the deciles (whiskers). Data in B and C have been log-transformed. Institution codes are shown in Table S1.

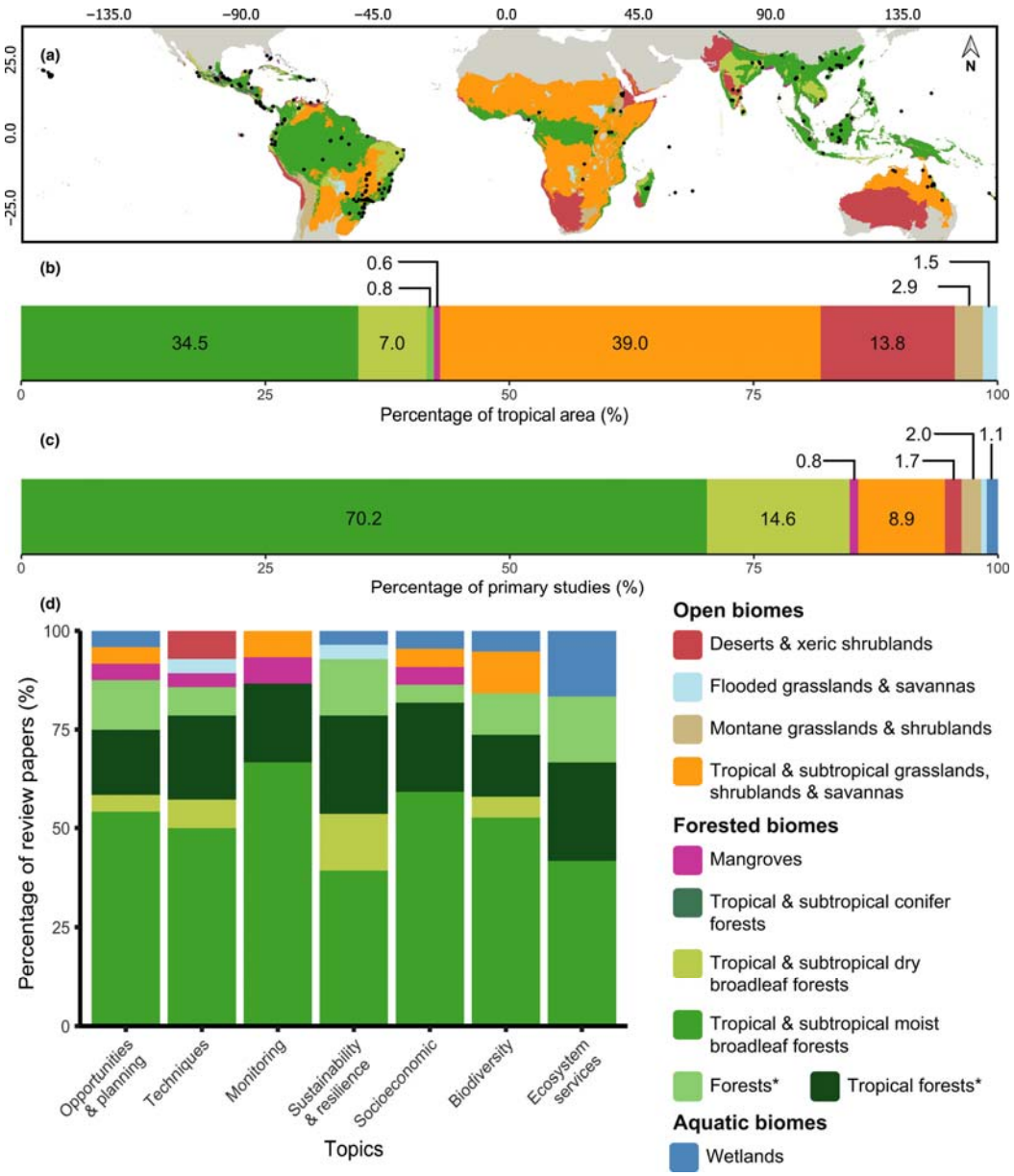

Figure 2. Awareness disparity in action and knowledge across the world's biomes. Global distribution of tropical biomes following Dinnerstein et al (2017) (A); percentage of tropical areas per biome (B); Percentage of primary studies addressing restoration of each from the tropical biomes (C); Percentage of review papers addressing different stages of restoration projects for different biomes (D).*Since some reviews discussed restoration of forests or tropical forests in general, we did not assigned them to a specific biome, but classified them in one of these broad categories.

We found strong disparities in action across tropical biomes (Fig. 2A), with restoration studies concentrated in rain forests (~70%), dry forests (15%) and mangroves (0.9%) (Fig. 2C). This disparity cannot be explained by area covered by forests ($\chi^2 = 284.4$, $p < 0.001$), since forest biomes cover around 43% of tropical and subtropical lands (Fig. 2B). Restoration in tropical and subtropical grasslands, savannas and shrublands were strongly underrepresented in restoration studies (8.9% of the cases *vs.* 39.0% tropical area. The strongest disparities in restoration actions occurred for deserts and xeric shrublands, which were the least represented biomes (Fig. 2B).

Our analysis revealed similar disparities in restoration knowledge (Fig. 2D), with review papers on restoration disproportionately concentrated on forests, accounting for 85% of publications. This suggests that the scientific community has disproportionately developed knowledge on restoration policy, science and practice for tropical forests, relative to knowledge available for open biomes (Fig. 1C). Tree planting was the most used and studied restoration technique and was the most common restoration strategy even in open biomes. The average number of citations of primary papers published in 2010-2015 did not differ between forest and open biomes (Deviance=1.2; p= 0.21).

Discussion

BAD is bad

Our results suggest that BAD not only exists, but it is also pervasive in tropical ecosystem restoration. Indeed, we found strong disparities in attention and interest relative to biome extent and diversity, with tweets focused disproportionately on forest restoration. Similarly, we found that restoration studies are concentrated in forest

biomes. Because these results indicate failures to recognize the importance and understand the ecology of overlooked biomes, we suggest that until BAD is addressed and fixed, ill-conceived conservation and restoration policies will threaten to exacerbate degradation and neglect of open biomes across the tropics and subtropics (Fleischman et al., 2020; Silveira et al., 2020). Tree planting in open biomes can be highly detrimental to biodiversity and ecosystem services (Veldman et al., 2015), but despite this, tree planting campaigns currently have high levels of popularity, social engagement and funding well beyond academic circles (Zhong & Dixon 2020). Reducing BAD in tropical and subtropical savannas and grasslands should be prioritized to maximize co-benefits of protecting biodiversity (Murphy et al., 2016) and securing ecosystem services provided by these open biomes (Zhao et al., 2020), a priority that partly reflects that tropical savannas and grasslands are home to 20% of the global population (Lehmann & Parr 2016). Large areas of tropical grasslands are degraded and in need for restoration projects (Bardgett et al., 2021), thus fewer restoration projects in these regions do not mean they are less degraded. Whilst deserts and xeric shrublands are the most poorly represented in our study (Fig. 2b) and are suffering increasing degradation worldwide (Martínez-Valderrama et al., 2020), they are less inhabited (1.7% of the world population; Martínez-Valderrama et al., 2020).

Agroforestry and afforestation in open biomes are being implemented widely in sub-Saharan countries (Djenontin, et al., 2021), India (Coleman et al., 2021), China (Cao et al., 2011) and Brazil (Martinelli et al., 2019), despite repeated warnings and robust evidence of the harmful consequences of such tree planting to ecosystem services, biodiversity conservation and human livelihoods (reviewed by Fleischman et al., 2020). Tree plantations may result in a reduction in net carbon sequestration or an increase in net emissions relative to previous land-cover types, such as grassland or

peatland, and may divert attention from efforts to reduce emissions from deforestation and degradation (Sutherland et al., 2021). Indeed, decades of tree planting and afforestation in India (Coleman et al., 2021) and China (Hua et al., 2018) has had little positive effect on forest extent and rural livelihoods.

Our analysis of primary research and review articles demonstrated that forests are far overrepresented in the scientific literature relative to open biomes (Fig. 2). We are concerned that such disparities in knowledge undermine the chances of successful ecosystem restoration. For example, a recent multicriteria approach that intended to identify priority areas for restoration across all terrestrial biomes (Strassburg et al. 2020) may notbe truly "optimized" because of knowledge gaps in the restoration of open biomes (Buisson et al., 2021), and because of forest biases in the selection of optimization criteria (e.g., potential carbon stocks, which tend to be higher in forests than open biomes).

Fixing Biome Awareness Disparity

To overcome BAD will require solutions that enhance restoration policy, science, and practice for all biomes, not just those with high tree cover. Below, we suggest the first steps to improve awareness of undervalued ecosystems, reduce existing disparities, and steer restoration policy and science during the UN Decade of Ecosystem Restoration.

1. *Decrease disparities through improved education*. Future scientists and policymakers should be taught to recognise that tropical biodiversity extends beyond rainforests (DRYFLOR 2016; Murphy et al., 2016). This will require educators, from primary school through the university level, to include open biomes in curricula and teaching

materials, as a means to decrease disparities (Brownlee et al., 2021). As evidence of this need, in Brazil, the Cerrado has lost more than 50% of its original area (higher destruction than Amazonia), yet, open biomes, like the savannas of the Cerrado, are poorly represented in postgraduate restoration courses, and tree planting is still the most commonly taught restoration technique (Sansevero et al., 2018).

2. *Change vocabulary, misperceptions and biases*. The use and misuse of certain terms contributes to misunderstanding of degradation processes and underemphasizes impacts on open biomes. One such problem is the use of 'potential vegetation' relative to current tree cover as an indicator of 'degradation' (Veldman 2016); low tree cover in tropical regions is not a reliable indicator of degradation, and likewise, high tree cover does not always equate to forest (Ratnam et al. 2011). Another case is the term 'savannization,' which when used in a negative manner (e.g. Nobre et al., 2016) to describe severe forest degradation (Table S4) can inadvertently malign natural, ancient grassy biomes (Veldman, 2016). Conversely, the terms afforestation (i.e. converting grasslands and savannas into planted forests), agroforestry and woody encroachment (Shindler et al 2011; Martinelli et al., 2019; Martin et al., 2021), even when they pose a threat to the ecological integrity of naturally open biomes (Veldman et al., 2015).

3. *Better mapping open biomes.* The persistent misuse of 'forest' to describe savannas with scattered trees is unhelpful and ultimately detrimental for conservation, because classification as 'forest' tends to lead toward tree-promoting, rather than grass-maintaining (e.g. prescribed fire), forms of management (Parr et al., 2014). Such misclassification permeates global vegetation maps which are biased towards forests. For example, large areas of savannas and grasslands in India, south-eastern Asia and Madagascar (Pennington et al., 2018) are misclassified as forests in Dinerstein et al.

(2017). We need to use accurate terminology and revised global vegetation maps to ensure open biomes in the tropics are better represented (Veldman et al., 2015).

4. *Decrease disparities in policy and knowledge.* Tropical and subtropical grasslands and savannas are notably underrepresented in both the UN Decade of Ecosystem Restoration Survey (http://decadeonrestoration.org/take-survey) and the Action Plan for the Decade on Ecosystem Restoration in Latin America and the Caribbean (2020). Biodiversity, ecosystem services, and human livelihoods in tropical grasslands and savannas are being damaged by inappropriate policies, such as afforestation and fire exclusion (Kelly et al. 2020). Thus, it is critical to ensure that the UN Decade on Ecosystem Restoration creates positive outcomes for these important and highly biodiverse ecosystems (Dudley et al., 2020). Given the greater knowledge gaps (e.g. Ribeiro et al., 2016; Martin et al., 2021), directing funding towards less-studied open biomes is likely to have a greater impact on conservation and restoration.

5. Decrease disparities in action and knowledge. From the perspectives of both biodiversity conservation and climate mitigation, it is vital that restoration efforts are undertaken across all tropical biomes. Forest-focused solutions (see Martin et al., 2021) will not protect the unique species found in open biomes. There are also substantial carbon gains to be accounted from conserving and restoring open biomes (Battle-Bayer et al., 2010). For example, grasslands may be more reliable carbon sinks than forests (Daas, et al., 2018). Ensuring that open biomes are included in the range of options available during the UN Decade on Ecosystem Restoration and beyond will substantially improve the success of mitigating climate change and protecting biodiversity.

Conclusion

BAD leads to tree-centric restoration approaches that are inappropriate for many species-rich open biomes that provide essential ecosystem services to a large proportion of the world's population. Because BAD is detrimental to the goals of the UN Decade of Ecosystem Restoration, we suggest that reducing BAD is essential for the success of ecosystem restoration across all tropical biomes. To be clear, reforestation efforts are important and have their place, but until open biomes receive similar attention, forest restoration initiatives will continue to forestall action to conserve the biodiversity, climate mitigation potential, and human livelihood benefits of open biomes. In short, as long as BAD exists, it will lead to bad conservation and restoration outcomes. We urge the global community of ecosystem restoration scientists, policy makers, and practitioners to recognise and appropriately address BAD so that the UN Decade of Ecosystem Restoration may achieve its goals.

Authors' contributions

FAOS, CAOP, LR and RTP conceived the ideas and designed methodology; CAOP and LCM collected the data; CAOP analysed the data; FAOS led the writing of the manuscript with significant contributions from LR, RTP, JWV. All authors contributed critically to the drafts and gave final approval for publication.

Conflict of interest

The authors declare no conflict of interest

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Data Availability Statement

Data available via the Dryad Digital Repository https://doi.org/10.6084/m9.figshare.16778200.v1 (Silveira et al., 2021).

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