

Restoring degraded land: contributing to Aichi Targets 14, 15, and beyond

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Restoration ecology is gaining momentum on the international conservation scene. In particular, restoring degraded ecosystems is central to Aichi Biodiversity Targets 14 and 15 set by the Convention on Biological Diversity. Depending on the definition of degradation, from 2 to 47% of the global land surface could require restoration. Here, we review the range of goals and approaches to restoration, from active interventions to more passive approaches such as rewilding. We identify biodiversity offsets, payments for ecosystem services and agri-environmental schemes as enabling policy mechanisms for restoration. Finally, we assess national conservation targets to examine the potential multifaceted impacts of achieving Aichi Targets 14 and 15 on biodiversity and society.

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Introduction

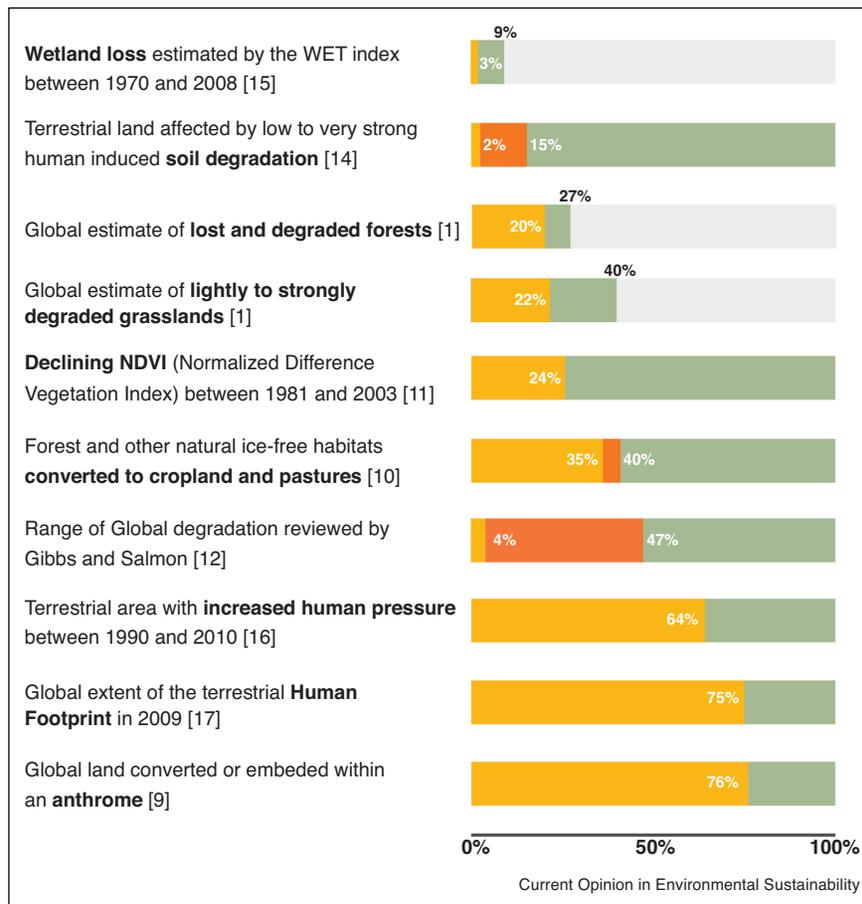
Ecosystems continue to be degraded faster than they are restored, and both the species and the human communities relying on them are increasingly affected negatively [1,2]. To address this issue, the restoration of the structural, functional and compositional dimensions of degraded ecosystems [3**] was made a key component of the Aichi Biodiversity Targets 14⁹ and 15¹⁰ [1,4] designed by the Convention on Biological Diversity (CBD). Target 14 focuses on restoring and safeguarding the ecosystems that provide essential services for human well-being while Target 15 aims at restoring degraded ecosystems to improve their resilience to disturbances and to support climate change mitigation and adaptation.

Restoration was also recognized as an important overarching contribution to achieve the goals of the UN Convention to Combat Desertification (e.g. Zero Net Land Degradation), the UN Convention on Climate Change (e.g. climate change mitigation), the Ramsar Convention on wetlands [5], the Convention on Migratory Species, and the Sustainable Development Goals (SDG 6 Target

⁹ 'By 2020, ecosystems that provide essential services including services related to water, and contribute to health, livelihoods and well-being, are restored and safeguarded, taking into account the needs of women, indigenous and local communities, and the poor and vulnerable'.

¹⁰ 'By 2020 ecosystem resilience and the contribution of biodiversity to carbon stocks has been enhanced, through conservation and restoration, including restoration of at least 15 per cent of degraded ecosystems, thereby contributing to climate change mitigation and adaptation and to combating desertification'.

Figure 1



Estimates of land degradation and human pressure. Land affected globally by human pressure and/or assessed as degraded. Figure adapted from [1]. Orange bars represent the percentage of terrestrial area affected. Darker orange tones are used to distinguish the upper and lower estimates when both values are provided in the study. For wetlands, forests, and grasslands, the figure also provides the estimate of the global ice-free terrestrial area covered by each of those ecosystems (values indicated above the green bars).

6, SDG 14 Target 2 and SDG 15) [6]. The choice of ‘Land Degradation and Restoration’ as the second thematic assessment conducted by the Intergovernmental Science-Policy Platform on Biodiversity and Ecosystem Services¹¹ reinforces the policy relevance of restoration and the urgency to adopt strategies worldwide [3^{••},5].

Despite this momentum, the fourth Global Biodiversity Outlook indicated that neither targets were on track to be achieved by 2020 [1]. Here, we review the motivations, approaches and mechanisms enabling or supporting the restoration component of Targets 14 and 15, with a focus on terrestrial ecosystems. We further address the cost-benefits of restoration and how current national biodiversity strategies reflect the synergies between Targets 14 and 15, and other Aichi Biodiversity Targets. We conclude by reiterating the potential of restoration for a broad long-term impact on biodiversity and society, in

¹¹ <https://www.ipbes.net/deliverables/3bi-land-degradation>.

support of, but also beyond, the 2020 strategy for biodiversity.

Why restore?

Most ecosystems and the services they provide are used unsustainably [7]. Human pressure and the associated land degradation processes (e.g. soil erosion and overgrazing) lead to the reduction or loss of ecosystems functions, resilience and productivity [8] with consequences for biodiversity [9,10] and human well-being [7,11]. Despite the salient impacts of land degradation, global assessments of its extent vary widely (Figure 1), limiting adequate responses by the global community. Indeed, consensual indicators and definitions of land degradation are still missing, while the methods [12^{••}], metrics, systems and baselines [13] considered to assess it are not consistent. For instance, the global area of ice-free land considered as degraded ranges between 2 and 47% [1,11,12^{••},14,15], while between 35 and 76% of the land is considered as being affected by human activities [9,10,16,17] (Figure 1).

In order to respond to a wide range in both pressures on ecosystems and the resulting degree of degradation, specific goals of restoration actions should also vary.

Restoration projects can be designed to restore habitat structure, species populations and communities, and/or ecological processes for the sake of biodiversity conservation [3**,8,18]. Multiple objectives can be addressed simultaneously, for example, when the restoration of species or populations is motivated by their role in key processes for shaping and maintaining ecosystems' structure and functioning [19,20*,21]. Addressing both the structure and function of degraded systems also contributes to long-term ecosystem resilience [3**,22,23] and the mitigation of climate-change effects [24,25], both essential to Target 15.

Restored lands can also supply ecosystem services, in line with the objectives of Target 14. Restoration followed by sustainable ecosystem use can improve both provisioning services and livelihoods [25,26*,27,28]. Restored forests provide timber and non-timber products such as fiber and medicinal plants [25,26*,28], while soil restoration in formerly unsustainably cultivated lands improves the supply of food and clean water [22,27,28]. Restoration can also target regulating services, such as carbon sequestration, erosion control and flood mitigation [8,27,28,29**]. Additionally, cultural services can be improved when the restored landscapes have important recreational or cultural values [28] or when volunteering for restoration projects reconnects people with nature [3**,18].

Restoration initiatives focusing on biodiversity conservation or on bundles of ecosystem services can share each other's goals and build on existing synergies [8,29**,30–32]. One example is wetland restoration, which is targeted at a particular habitat and also restores the supply of a large number of ecosystem services [15,30]. However, these multiple restoration goals can sometimes be divergent and conflicting [18,32–35] (e.g. increasing carbon sequestration versus restoring the habitat of threatened species [34]). Furthermore, even when goals are shared, optimizing for one might lead to trade-offs with positive, albeit sub-optimal solutions for others [31].

Approaches for restoration

When designing a restoration strategy, spatial, temporal and financial aspects have to be considered [33]. Particularly contentious aspects are the role and perception of a historical state, as current degradation and future conditions might steer restoration on different paths from what is considered the baseline [13,33,36]. Aiming to restore ecosystems to their historical conditions may not be possible, nor sustainable [37]. Yet, several researchers recommend that the focus of restoration should be as often as possible on pre-degradation conditions and that environmental damages should not be deemed *a priori* irreversible [38,39]. Goals and methods can also be defined following a

long-term stepwise approach and reassessed as the condition of the ecosystem evolves [40]. The implementation of adaptive management that accounts for complex and dynamic socio-ecological systems is also encouraged by the CBD under the 'Ecosystem Approach' [41]. Similarly, approaches focusing on re-establishing natural ecosystem processes without setting *a priori* explicit goals — or 'open-ended conservation' — have been suggested, for instance, for large and/or remote areas that are expected to be impacted by future climate change, or for which the initial ecosystem conditions cannot be replicated [42].

When the objective is to attain rapid benefits, or when degradation is too intense, restoration can involve active interventions, both biotic and abiotic, such as invasive species control, structural management of vegetation, or soil amendment [8,22,30]. Seeding and planting are also common practices for active restoration [18], with candidate species depending on the restoration goal, for example, carbon sequestration [24] or restoring native communities [25]. Occasionally, 'assisted' forms of recovery can be preferred, with time-limited interventions setting the system on a restoration path [3**,23,33,43]. Those interventions are for instance the (re)introduction of ecosystem engineers (i.e. species that modify their abiotic environment [21]), for instance beavers in wetlands [44], and keystone species [20*].

More recently, following the large scale abandonment of marginal and less productive lands world-wide [9,10], more passive approaches to restoration have been considered [36]. One of them is 'ecological rewilding' (i.e. the passive restoration of ecological successions and processes while reducing the human control of landscapes [19,43]). How biodiversity responds to ecological rewilding depends on the taxa and the landcover transitions following abandonment. Large European mammals and forest species, for example, already benefit from reduced human pressure and increased land availability [43].

Restoration strategies for 'novel ecosystems' have also recently received attention [32]. Although the definition of novelty remains strongly debated [38], the term is usually applied to stable ecosystems that are greatly modified by human activity. Among the many possible modifications, the presence of non-native species and land-use changes are often the most conspicuous (e.g. [39,45]) and some argue that restoration practices should retain or even foster part of this novelty (e.g. [37,46]). However, this is also viewed as 'lowering the bar' in restoration practices and a legitimization of the increasing environmental degradation caused by humans [38,39].

Prioritization of restoration actions

The prioritization of goals, locations and approaches is crucial to restoration success due to limitations in resources for most projects. Optimization tools aimed to

address ecological restoration planning and prioritization should take into account: objectives and actions; spatial aspects; cost–benefit; degradation states; and the likelihood of success [47]. However, in real-life, data limitations often make such frameworks difficult to apply. Indeed, most case studies of restoration prioritization consider only few joint aspects of the restoration problem, and typically only one restoration goal. One of few studies that compared restoration prioritization with several goals, at the scale of the European Union, showed that focusing on habitats achieves larger benefits than focusing on species or ecosystem services [48]. However, this approach has also been criticized for its conceptual and operational limitations, hence emphasizing the need to explicitly account for data assumptions in prioritization exercises, particularly considering their policy implications [49,50].

When the outcome of prioritization exercises for restoration actions imply removing land from production of goods, it is sometimes hypothesized to cause land-use displacement to satisfy demand. This may lead to degradation elsewhere (e.g. [26*]). While this is not likely to be the case when considering restoration on marginal and abandoned lands [43,51], in other instances restoration actions could be designed to combine development goals for sustainable forestry and agriculture [26*,29**,51], hence maximizing the ecological and social benefits of future management.

Mechanisms promoting restoration

Several mechanisms and policies developed to reconcile development activities and environmental conservation can also promote land restoration [23].

No Net Loss policies (NNLp), supported by a mitigation hierarchy, aim to ensure that no biodiversity or ecosystem services are lost due to development projects [52]. Biodiversity offsets are one of the mechanisms within NNLp that can promote restoration. They should balance unavoidable biodiversity loss in one place, at one point in time, by an equivalent biodiversity gain elsewhere, within a pre-agreed time period [52]. The Clean Water Act in the USA and the European No Net Loss initiative are such policies that support biodiversity offsets [53]. Yet, offsets still present many conceptual and practical challenges, such as the notion of equivalence in the compensation of the loss and the need for long-term monitoring of performance [53,54].

Payments for Ecosystem Services (PES) monetize the supply of ecosystem services and remunerate practitioners for managing the land accordingly [55–57]. The Chinese ‘Grain-for-Green’ program [24,27] and the REDD+ mechanisms [35] are examples of PES for soil restoration and climate-change mitigation. Nonetheless, PES are also controversial as the focus on one class of ecosystem services can be at the expense of biodiversity

conservation [34,35]. Moreover, the socio-economic contexts (e.g. land-tenure security) must be considered carefully, to engage a large array of landowners and ensure long-term sustainability [57].

Agri-environmental schemes (AES), as applied in the European Union, promote wildlife-friendly agriculture and support its biodiversity and cultural values [27,29**] by paying subsidies to landowners to cover the income foregone and extra-costs resulting from their commitment. For instance, subsidizing hedgerows and woodland islets [27] could restore connectivity and would further facilitate restoration if the fields were to be abandoned [43]. However, the biodiversity outcome of AES is debated and combining approaches is suggested to improve those outcomes (i.e. subsidizing actions to create or maintain habitats that support biodiversity on intensive agriculture and restoration via rewilding on marginal lands [51]).

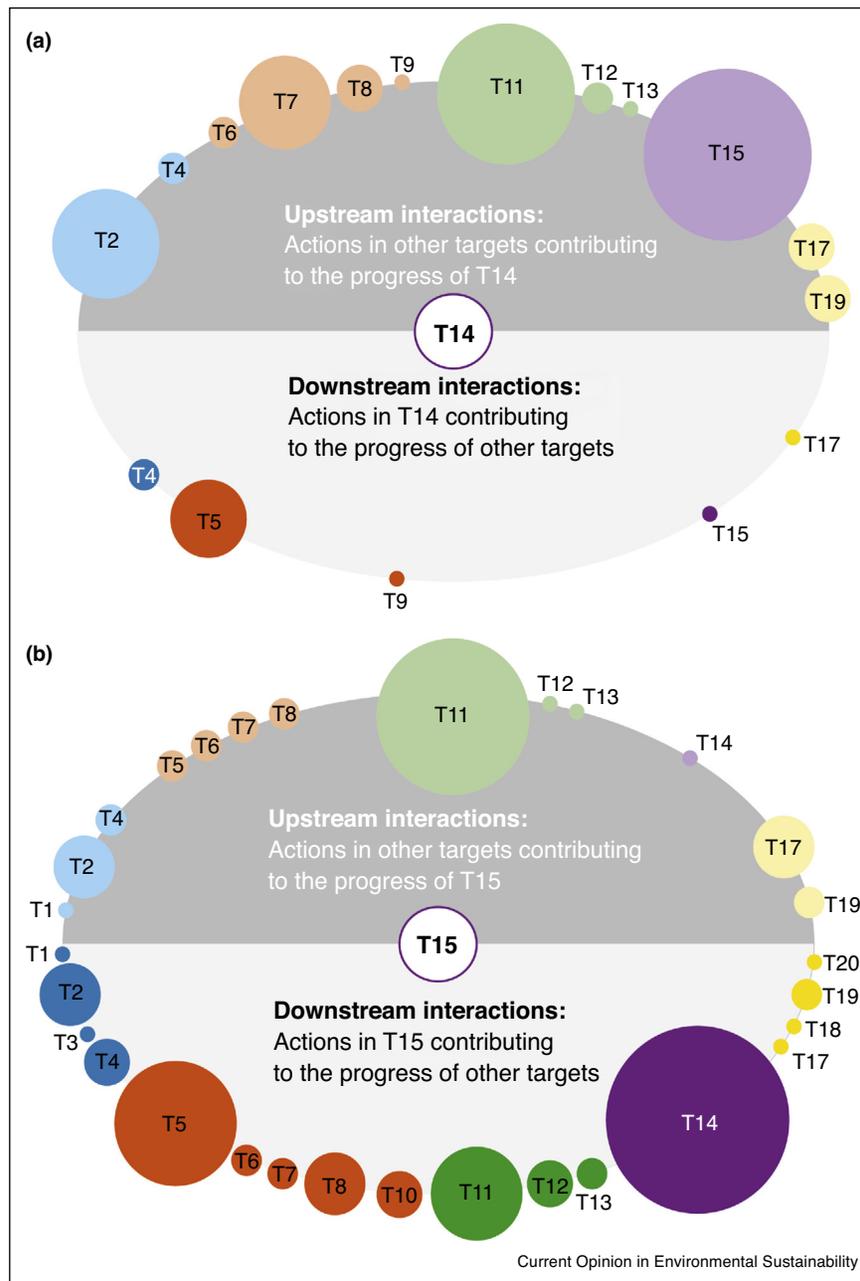
Cost–benefits of restoration

Restoration is often perceived as costly for society [58*,59]. Estimates of the average annual expenditure (2013–2020) for Target 14 range between US\$3.8 and US\$37.5 billion (with a portion of the budget dedicated to restoration), and was estimated at US\$6.4 billion for Target 15 [60], including costs associated with restoration actions and subsequent management and monitoring [61]. These estimates represent less than 10% of the total annual expenditure estimated for all 20 Aichi Targets [60], and do not account for interactions and synergies between targets or with other conservation policies [60,62]. Furthermore, an analysis estimating the return on investment of restoration projects, using 225 studies with reported benefits and

Box 1 Method to assess the downstream and upstream interactions around Aichi Biodiversity Targets 14 and 15 (Figure 2).

In their ‘post-Nagoya’ National Biodiversity Strategies and Action Plans (NBSAPs), Parties of the CBD define national biodiversity conservation ‘targets’ or ‘actions’ (hereafter actions). These national actions may map to one or several of the global Aichi Biodiversity Targets (www.cbd.int/nbsap/targets). To assess interactions among global targets, we selected national actions related to Aichi Biodiversity Target 14 or 15 (Figure 2a and b respectively), and at least one other Aichi Biodiversity Target. For each of those national actions, we identified which was the ‘main’ Aichi Biodiversity Target associated to it, based on their formulation and content. The remaining Aichi Biodiversity Targets associated with this national action are then considered as ‘related’ to this main Target. In particular, this approach allows to identify upstream and downstream interactions [62] between targets: actions taken to achieve a given target can influence the achievement of other targets (i.e. downstream interactions) while some targets might be influenced by actions taken to achieve other targets (i.e. upstream interactions). In this assessment, the ‘main Target’ identified will have downstream interaction on the ‘related Targets’, and vice versa. By applying this method, we identify and quantify the upstream and downstream interactions with both Targets 14 and 15 based on biodiversity conservation actions defined at the national level within the NBSAPs (Figure 2).

Figure 2



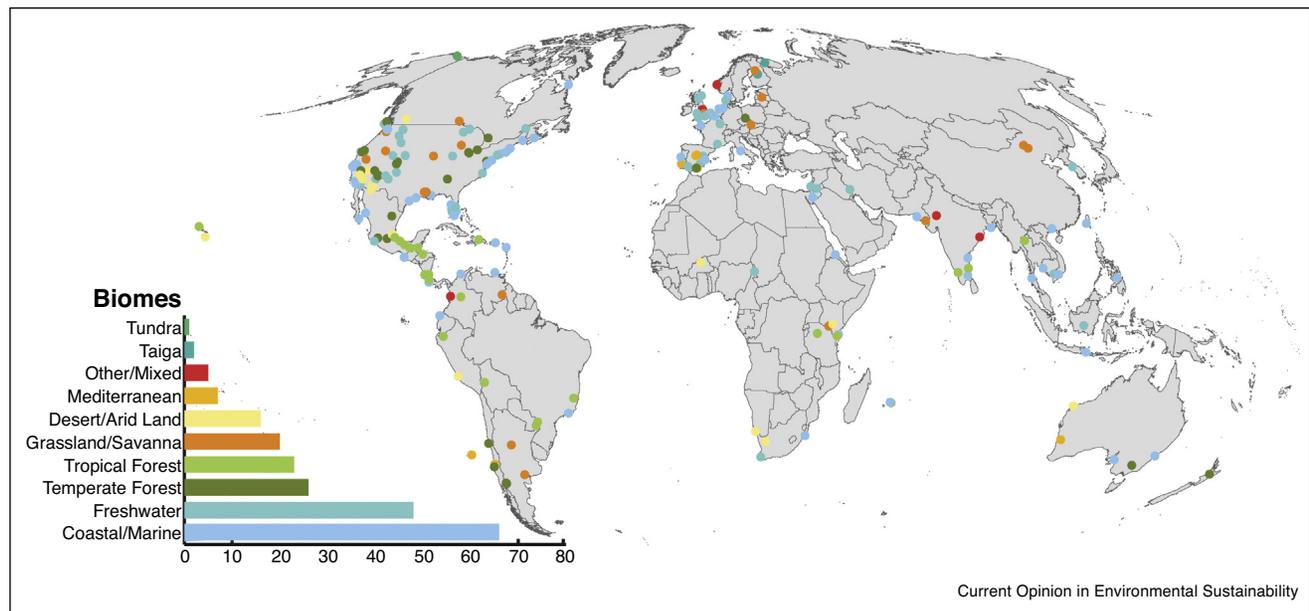
Downstream and upstream interactions of Aichi Targets 14 (a) and 15 (b). The size of the circles is proportional to the number of national actions where interactions between Targets 14 and/or 15 and the remaining Aichi Biodiversity Targets were found (see Box 1 for a detailed methodology of the assessment approach). The colors of the circles represent the five Strategic Goals in the CBD Strategic Plan for Biodiversity 2020: “A ‘Mainstreaming biodiversity’ – blue, B ‘Reduce direct pressure’ – orange, C ‘Improve status’ – green, D ‘Enhance benefits’ – purple, E ‘Enhance implementation’ – yellow”.

94 with reported costs, showed net benefits in six out of the ten studied biomes, in both developed and developing countries [61]. Nevertheless, the temporal disconnection between the allocation of funds and the time when the first benefits are perceived complicates the assessment of such cost–benefits [24,33]. Furthermore, the local cost of restoration is often disconnected from the wide public

benefits that reach stakeholders regardless of their individual contribution to the restoration action [61].

Assessing and disclosing the socioeconomic benefits provided by ecosystems can nonetheless encourage restoration [23,30,59,61] since both the restoration action *per se* and the restored land have potential for employment and

Figure 3



Geographical bias in restoration information. Number of restoration projects listed in the Global Restoration Network database, color-coded by biome type ($N = 204$ in February 2017, <http://www.globalrestorationnetwork.org/>). Figure adapted from [1].

increased livelihoods, and well-being [25,27,58*]. For instance, the ‘restoration economy’ in the USA was estimated to nearly US\$25 billion in annual economic output [58*]. Therefore, restoration should be considered an investment rather than a cost [61].

Achieving restoration-related targets

The achievement of a given Aichi Biodiversity Target can be assisted by actions taken to achieve other targets (i.e. upstream interactions) [62]. Similarly, actions taken for a particular Target may contribute to other Targets (i.e. downstream interactions). We assessed the Targets and national actions in the biodiversity strategies developed by parties of the CBD and the different upstream and downstream interactions centered on Targets 14 and 15 (Box 1, Figure 2). As expected, national actions for both Targets 14 and 15 are strongly linked, but we also identified numerous up and downstream interactions with almost all the other 18 Targets. Target 14 (Figure 2a), on the restoration and safeguarding of ecosystem services receives a strong upstream influence of actions designed to preserve biodiversity (Target 11), enhance its valuation (Target 2) and promote sustainable land-use (Target 7). The pattern for Aichi Target 15 shows considerably more downstream interactions (Figure 2b): actions designed to achieve the Target could have a positive impact on nearly all other Aichi Biodiversity Targets, particularly on habitat loss (Target 5).

The fact that many countries defined restoration actions in their national biodiversity strategies for 2020 is encouraging,

and so is the identification of interactions with other conservation Targets. Capacity building, knowledge exchange and long-term standardized monitoring are essential to support the implementation of those restoration actions and the achievement of global Targets [23,25]. Although thousands of restoration projects have been implemented [23], the most comprehensive database shows a strong geographical and biome bias in the documentation of projects and data availability (Figure 3). Furthermore, to date the only indicator available for Target 15, produced by the UNCCD, focuses on the proportion of land degraded over the total land area of countries. The spatially and temporally relevant indicator for Target 14 is limited to the Red List Index of pollinators [2], which shows a strong negative trend. We urgently need both the development of adequate indicators to monitor the progress in achieving both Targets and increased efforts in documenting and reflecting on restoration projects while improving their geographical representativeness. This will also contribute to capacity building. Transboundary collaboration should also be fostered as many benefits of restoration are not spatially restricted to a restored site but shared over larger areas or communities [61].

Conclusion

Considering the current knowledge, initiatives and national aspirations, restoration is on the path to become a priority in responding to ecosystem degradation. It is a valuable long-term investment for biodiversity and society that can be reconciled with sustainable development.

As multiple upstream and downstream interactions between conservation targets are identified, restoration can also play a role in facilitating the achievement of multiple Aichi Biodiversity Targets, beyond Targets 14 and 15. Similarly, synergies could be investigated between the restoration component of Targets 14 and 15 and other objectives of Multilateral Environmental Agreements such as the UNFCCC and the UNCCD. Nonetheless, research is still needed to assess the trade-offs and synergies between restoration approaches in terms of ecosystem composition, structure, function and services. Future efforts should also be placed in the monitoring of both degradation and restoration and the development of indicators. However, the opportunities offered by restoration cannot justify degradation of undisturbed ecosystems or its aggravation when ecosystems are already modified. Priority should still be on averting land degradation, as this is the most efficient way of safeguarding ecosystems.

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