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# Land Restoration in Latin America and the Caribbean: An Overview of Recent, Ongoing and Planned Restoration Initiatives and Their Potential for Climate Change Mitigation

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**Abstract:** Land degradation is a globally recognized problem and restoration of degraded land is currently high on the international agenda. Forest landscape restoration and other restorative ecosystem management activities are important measures that contribute towards reaching the objectives of the Bonn Challenge, which aims to restore 350 million hectares by 2030. In this context, many restoration projects are being planned and implemented in Latin America and the Caribbean (LAC). We present an overview of the location, goals and activities, and an estimated climate change mitigation potential of 154 recent, ongoing and planned restoration projects in LAC. Our analysis suggests that most projects are located in the humid tropics and less attention is paid to drylands. Increasing vegetation cover, biodiversity recovery and recovery of ecological processes are the most common goals. Restorative activities to fulfil these goals were diverse and were related to the type and source of funding that projects receive. For example, projects implemented through the Forest Investment Program (FIP) and the Global Environment Facility (GEF) generally rely on natural or assisted regeneration over large areas (>20,000 ha), whereas Clean Development Mechanism (CDM) projects establish forest plantations, often including exotic monocultures, in smaller project areas (<5000 ha). Projects that are specifically implemented within the scope of Initiative 20 × 20 and other local initiatives that target the local environmental problems, are more varied and rely on a wider portfolio of restorative activities, such as erosion control, exclusion of grazing and mixed plantations. These projects are usually implemented in smaller project areas (<5000 ha). All projects had the potential to contribute to climate change mitigation by storing additional forest aboveground biomass through natural regeneration, assisted regeneration or establishing a plantation. Further analysis of the implemented activities is an important next step to investigate their effectiveness in terms of goals achieved under Initiative 20 × 20 and the Bonn Challenge. This would provide information for future restoration projects and upscaling of restorative activities in a wider area.

**Keywords:** forest landscape restoration; ecological restoration; forest biomass; climate change mitigation; comparative analysis; Latin America and the Caribbean

## 1. Introduction

Political momentum has renewed awareness of the land degradation problem globally. Countries are relying on multiple international and regional policy initiatives to address the causes of degradation (such as Sustainable Development Goal 15 and the Convention on Biological Diversity Aichi Target 15) to develop national restoration frameworks and to take action to restore ecosystems and landscapes where they have already been compromised [1,2]. The Bonn Challenge, launched in 2011 by the German government and the International Union for the Conservation of Nature (IUCN), and later endorsed at the United Nations Climate Summit in 2014, aims to restore 150 million hectares of deforested and degraded lands by 2020 and 350 million hectares by 2030 [3]. As a response to the Bonn Challenge the country-led effort Initiative 20 × 20 was introduced in 2014 with the aim of restoring 20 million hectares of degraded land by 2020 in Latin America and the Caribbean (LAC) [4]. This initiative is supported by the World Resources Institute (WRI), International Center for Tropical Agriculture (CIAT), Centro Agronómico Tropical de Investigación y Enseñanza (CATIE), and the IUCN. WRI supports facilitation and fosters cooperation and dialogue among governments, civil society, and the private sector to support countries to meet their restoration commitments. With 17 countries participating in Initiative 20 × 20, together pledging 53 million hectares of land for restoration [4], LAC are in the forefront, with countries like El Salvador initiating the Declaration of the UN Decade of Ecosystem Restoration 2021–2030 to energize existing commitments and mandates [5].

There are many approaches to restoring degraded ecosystems and landscapes. Ecological restoration is seen as a key strategy to assist in the recovery of an ecosystem that has been degraded, damaged, or destroyed [6,7]. It is defined as the process of removing degradation and returning the system to the state it would have been in now, if degradation had not occurred [7] and aims at restoring ecological functions and processes, and the biotic community structure of the original ecosystem, and thereby may contribute to enhancing biodiversity, increasing the provision of ecosystem services, and sequestering carbon in second-growth forests [8–11]. Another approach, forest landscape restoration (FLR), is seen as a major strategy to fulfil the goals of the Bonn Challenge and Initiative 20 × 20. FLR is distinct from ecological restoration (ER) as it may include many types of ecosystem management activities in different ecosystems and land uses (including, but not limited to ER activities). It is a process of regaining ecological functionality while at the same time aiming to enhance human well-being across deforested or degraded forest landscapes [12]. This can best be achieved through a landscape approach which considers ecological, social and economic benefits of forests and trees within a broad range of land uses. Restorative activities such as afforestation and reforestation are also seen as cost-efficient ways to meet the mitigation targets to limit global warming to 1.5 °C [13]. Lewis et al. [14] argue that regenerating natural forest would be the best option for restoration as this would store more carbon than tree plantations or systems where crops grow together with trees, such as agroforestry.

In this paper we focus on the broad range of potentially restorative ecosystem management activities in LAC. These encompass both ER and FLR activities. We will use the term "restorative activities" to denote these types of ecosystem management activities. We will use the term "restoration" in a broad sense, referring to both ER and FLR, and we will use the term "restoration project" to refer to a project that implements any of these types of restorative activities.

Within the tropical domain, the South American continent, together with Africa, was estimated to have the highest net forest loss between 1990 and 2015 [15]. Having four countries in the top ten of countries reporting the greatest annual net loss of forest area between 2010 and 2015, and with Brazil leading this list, deforestation and forest degradation are major problems in this continent [15]. Most deforestation in South America is due to conversion of forest into pasture (71%), while commercial cropland is the second largest driver of deforestation (14%) [16]. With a relative contribution of more than 70%, timber extraction and logging are the most important drivers of forest degradation [17]. From a legal perspective, countries like Brazil and El Salvador already count on national restoration strategies that have been transposed into national legal frameworks [18]. From a research perspective, new data have been produced on climate change mitigation potential for natural regeneration in

lowland tropical Central and South America [9]. Chazdon et al. [9] found that natural regeneration can be a low-cost mechanism that can potentially sequester high amounts of carbon in second-growth forests. A recent paper by Coppus et al. [19] analysed the characteristics of 97 restoration projects across the continent using multivariate techniques to develop a typology of restoration projects. The analysis showed that type of funding is a key variable to discriminate restoration projects.

Restoration projects vary in temporal and spatial scale and especially FLR projects can have multiple goals to generate socio-economic and environmental benefits. Goals may include job creation, improvement of livelihoods, and enhanced land productivity for socio-economic impact; and improving ecosystem functionality, biodiversity conservation and climate change mitigation for environmental impact [20]. Different types of activities can be used to achieve the these goals, ranging from passive (e.g., natural regeneration, fencing, removing grazing animals) to active (e.g., assisted regeneration, large-scale plantation) [21]. Active interventions can also include agro-forestry and silvopastoral systems, which combine land restoration with sustainable agricultural productivity. Progress in restoring degraded land across LAC is being made. However, there is currently no clear overview of what is happening on the ground and information about location, goals, activities, and potential for mitigating climate change of restoration projects in LAC is dispersed or lacking. There might be differences in project characteristics across different initiatives, stemming from their own global purpose, and this type of information would be important to improve understanding of the scope of ongoing and planned restoration projects and initiatives, and to learn from implemented activities, for scaling up of restorative activities (i.e., implement activities at large spatial scales). Scaling up is currently seen as the corner-stone for achieving the ambitious restoration targets that LAC countries have pledged under the Bonn Challenge [22,23]. Analysis of current restoration projects could similarly provide insights into the progress that is being made by projects towards fulfilling the Bonn Challenge goals.

The first objective of this paper is to provide an overview of planned, ongoing and finalized restoration projects in LAC and to describe their characteristics. Through a comparative analysis of five different initiatives the analysis focuses on visualizing and quantifying the differences in project size, project goals and restorative activities. This will provide more insight into different programmes and initiatives and how they are prioritising their activities. The second objective is to get an understanding of the climate change mitigation potential for these initiatives by estimating the amount of additional forest biomass that can be accumulated when the areas would be restored to their potential forested state.

## 2. Data and Methods

### 2.1. Restoration Initiatives

We centered the analysis around five different groups of restoration projects and used the common denominator "initiative" to refer to these. We define the initiatives by the type of funding that the projects receive, as this was found to be an important factor for differentiating different typologies of restoration [19]. Table 1 gives an overview of the five different initiatives analysed.

**Table 1.** Description of initiatives.

| Initiative | Description |
| --- | --- |
| **20 × 20** | This group consists of projects that are directly related to the country-led effort Initiative 20 × 20. These projects are mainly funded by the private sector and governments [4]. |
| **GEF** | This group includes projects that are funded by the Global Environment Facility (GEF). The GEF is an international partnership of 183 countries, international institutions, civil society organizations and the private sector that addresses global environmental issues. GEF projects aim to address global environmental issues, and one of the focus areas is to minimize land degradation, rehabilitate degraded areas and ensure the optimal use of land resources, mainly through sustainable land management [24,25]. |

**Table 1.** *Cont.*

| Initiative | Description |
|---|---|
| **FIP** | This group concerns projects funded by the Forest Investment Program (FIP). FIP is part of the Climate Investment Fund (CIF) which supports implementation of the international climate change agreement by enabling transformations in clean technology, energy access, climate resilience, and sustainable forests in developing and middle income countries through large-scale, low-cost, long-term financing [26]. FIP supports efforts of developing countries to implement REDD+. |
| **CDM** | This group of projects is funded by the Clean Development Mechanism (CDM), a flexible mechanism defined in the Kyoto Protocol. CDM implements emission-reduction projects in developing countries which allows them to earn certified emission reduction (CER) credits for capturing and storing $CO_2$. Projects include afforestation and reforestation activities that generate CER credits which can be traded and sold to industrialized countries in order to meet Kyoto targets [27,28]. |
| **Local** | This group includes various smaller scale projects led by local governments, non-governmental organizations (NGOs) and research organizations, and focuses on restoring degraded land and ecosystems in the local context and on smaller scale. This group of projects receives various types of funding, mainly by (sub)national governments or national or international donors and is labelled as "local" projects. |

GEF, FIP and CDM projects are funded by international donors.

We refer to these five groups as initiatives: "20 × 20"; "GEF"; "FIP"; "United Nations Framework Convention on Climate Change (UNFCCC) CDM"; and "local" throughout the analysis. Since the launch of initiative 20 × 20, any restoration project, and thus also projects from GEF, FIP, UNFCCC CDM and local initiatives, which in some cases already started earlier, may contribute to reaching the countries' restoration targets under Initiative 20 × 20. We look at each of these initiatives separately.

*2.2. Restoration Database, Map with Project Locations, and Comparative Analysis*

We developed a database with information on finalised, ongoing and planned ER and FLR projects in Latin America and the Caribbean. The database structure was adapted from the framework developed by Murcia & Guariguata [29]. The database comprises 154 projects with information on the biophysical and socio-economical setting and the approach used, with variables related to type of restoration initiative, geographic location, biome, goals and activities. In the Supporting Information Table S1 includes all variables and sub-variables contained in the database. For this study, we only used a few of the many variables that are available in the database. The database consists of 18 GEF projects, 19 UNFCCC CDM projects and 14 FIP projects. Information for these projects was available from project documents on their websites. In addition, we added 56 projects that are associated with Initiative 20 × 20. Project descriptions were provided by WRI or taken from the national inventories from Colombia, compiled by the Center for International Forestry Research (CIFOR) [29] or from Peru, compiled by Bioversity International, the World Agroforestry Center (ICRAF) and Servicio Forestal Nacional y de Fauna Silvestre (SERFOR) [30]. Furthermore, we added 47 "local projects" to the database. Data for these projects were assembled from several existing restoration projects databases for Mexico, compiled by the Center for International Forestry Research (CIFOR) [31], for Chile [32] and for Guatemala (data provided by WRI). In addition, three ongoing research projects in Colombia, Nicaragua and Peru, led by CIAT (International Center for Tropical Agriculture), were included. Information about these projects was obtained through interviews. From the national inventories and existing databases, we randomly selected between 10 and 20 projects each (representing 15% to 37% of the total number of projects in the databases), that started in 2000 or later (with some exceptions for Colombia) and covered an area of at least 10 ha (with some exceptions for Colombia and Chile). The projects in our database are not a representative sample for whole LAC, they are the totality of the information that was identifiable through our approach. For example, we looked at all FIP, GEF and CDM projects in the region, not a sample. There is a potential issue of non-representativeness of

the analysis for the category "Local" and "20 × 20". Our approach would only have identified such projects that establish a web presence or that communicate in national and international forums about what they are doing. The complete database is available for download via Harvard Dataverse and via the LUCID (Land Use, Carbon & Emission Data) portal at Wageningen University and Research; http://lucid.wur.nl/datasets/forest-and-landscape-restoration [33].

The restoration projects were mapped in a geographic information system (GIS), using the center point of the smallest available administrative unit as location (province/state, municipality). To define the biome in which a project was implemented, the classification of Olson et al. [34] was used. The comparative analysis focused on quantifying and visualising differences between initiatives for project size, project goals and restorative activities, with special attention to the types of plantations and origin of species used (native or exotic).

### 2.3. Assessment of Project Carbon Stocks and Associated Mitigation Potentials

To represent the current biophysical condition of the restoration projects, we estimated the current forest aboveground biomass (AGB) of the restoration areas with use of the GEOCARBON global forest AGB map, available via the LUCID portal (http://lucid.wur.nl/?viewDataset=9), which is based on Avitabile et al. [35,36] and Santoro et al. [37]. We overlaid the project boundaries (administrative units) on this map in order to determine the mean forest AGB (Mg/ha) for each project, and eventually we calculated the mean forest AGB (Mg/ha) for each type of initiative.

Subsequently, we produced a map of the entire LAC region that shows the amount of forest AGB (Mg/ha) that currently deforested and partially deforested/degraded areas can potentially accumulate when they are restored to more mature cover-dense forests. We call this "potential additional forest AGB", which is a proxy for the carbon sequestration potential associated to the transitioning towards a more mature secondary forest succession in a given biome. This sequestration potential is meant to navigate FLR managers on general mitigation potentials per biome (and their current gaps), rather than to offer accurate estimates of AGB carbon changes.

A detailed methodological description can be found in the Supporting Information. Table S2 in Supporting Information lists details about the input data for analysis of potential additional forest AGB. In short, the "potential additional forest AGB" was estimated combining data on 1. areas where there is potential for transitioning towards mature secondary forests (derived from the Atlas of Forest Landscape Restoration Opportunities (AFLRO) [38]) for each global ecological zone (derived from FAO Global Ecological Zones [39]), with 2. carbon data derived from the GEOCARBON global forest AGB map (mentioned above). The combination of areas with different forest densities (AFLRO) with carbon data (GEOCARBON) offers useful information to broadly estimate carbon sequestration potentials if we moved towards more carbon dense secondary forests within the same biome. Table S3 in Supporting Information includes all possible forest restoration opportunities (forest transition), based on different classes in ALFRO. Researchers have rightly raised concerns about the AFLRO not depicting regions with restoration opportunity but rather areas where forests can grow. In our case, we are limiting our analyses to areas where restoration activities are already happening and, therefore, the AFLRO maps are not used to navigate restoration. Another concern relates to whether AFLRO offers a realistic initial state. Thus, AFLRO offers information on areas where forests have changed cover densities (and therefore carbon densities) in relation to a potential initial condition. While the debate of 'what is the initial state' is legitimate, in our case it is irrelevant since we only use AFLRO areas to help us estimate different carbon densities. These differences are then expressed as the 'mitigation gap' that current FLR projects have (e.g., the current AGB carbon sequestration is potentially lower than what it could be considering more mature forest successional states in the same biome). Again, we do not use the Atlas map to navigate restoration, our goal is to raise awareness among FLR managers on areas with mitigation gaps since these areas deserve attention (e.g., acting on permanence risks) if mitigation was the goal of the restoration.

Areas that have no potential to become forested, such as agricultural areas, urban areas, water and other lands, were excluded from the map and further analysis. These areas were eliminated by overlaying the ESA Land Cover map from the Climate Change Initiative (LC-CCI) from 2015 [40] on the potential additional forest AGB map. We overlaid the project boundaries (administrative units) on this map in order to determine the mean "potential additional forest AGB" (Mg/ha) for each project, and eventually we calculated the mean "potential additional forest AGB" (Mg/ha) for each type of initiative.

## 3. Results

### 3.1. Geographic Distribution of Projects from the Various Initiatives

Many small projects (<1000 hectares) are located in Mexico, Colombia and Peru, as can be seen in Figure 1. These are mostly projects associated with Initiative 20 × 20, and local initiatives. Projects from GEF, CDM and FIP are spread over the whole continent, with most projects concentrated around the Amazon area. The background map with potential additional forest AGB values will be further explained in Section 3.3.
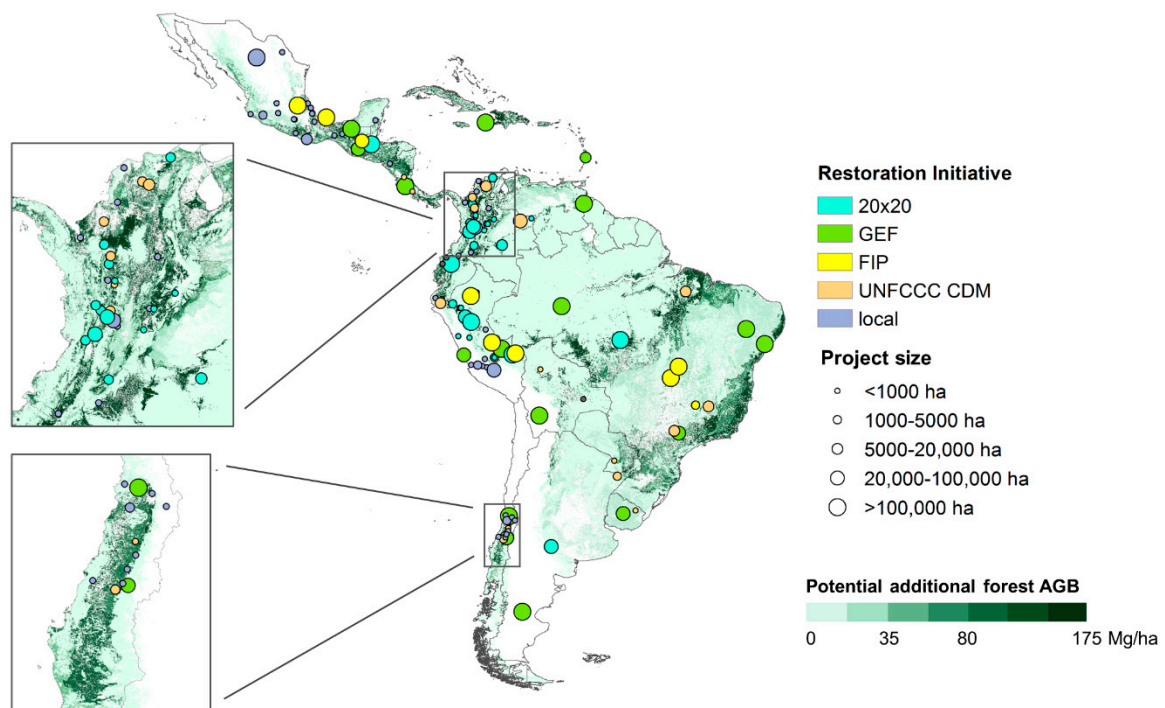


**Figure 1.** Map of 154 restoration projects in Latin America and the Caribbean projected on the map of potential additional forest aboveground biomass (AGB). The dots represent the centre location of the administrative boundaries of the restoration projects. Two areas in Colombia and Chile are shown in greater detail on the inset maps Note: an earlier version of this map was previously published as Figure 15.2 in Verchot et al. [41].

The majority of projects (99) is located within tropical or subtropical moist or dry broadleaf forests (see Table 2). A smaller number of projects (24) is located in Mediterranean forests, woodlands, and scrublands, or in temperate broadleaf and mixed forests (23 projects). Projects in other biomes occurred less frequently. Large scale projects (>100,000 hectares) are located mainly within tropical and subtropical moist broadleaf forests (17 out of 40) projects. Projects with an extent smaller than 100,000 hectares are spread over many biomes, still with highest concentration in tropical regions. CDM projects usually take place at a small scale (less than 20,000 ha) (see Table 3). Also, many projects associated with initiative 20 × 20 and local projects are implemented at a small scale (<1000 ha or 1000–5000 ha). GEF and FIP typically implement large scale projects (>100,000 ha).

**Table 2.** Number of restoration projects within various World Wide Fund for Nature (WWF) biomes [34], sorted by project size. A project can cover multiple biomes.

| WWF Biomes | Extent of Restorative Activities Per Project (Hectares) | | | | | |
|---|---|---|---|---|---|---|
| | <1000 | 1000–5000 | 5000–20,000 | 20,000–100,000 | >100,000 | Total Projects |
| Tropical and Subtropical Moist Broadleaf Forests | 35 | 9 | 4 | 5 | 17 | 70 |
| Tropical and Subtropical Dry Broadleaf Forests | 13 | 7 | 4 | 1 | 4 | 29 |
| Tropical and Subtropical Coniferous Forests | 2 | - | - | 2 | 3 | 7 |
| Temperate Broadleaf and Mixed Forests | 19 | 2 | - | 1 | 1 | 23 |
| Tropical and subtropical grasslands, savannas, and shrublands | 5 | 2 | 2 | 3 | 4 | 16 |
| Temperate Grasslands, Savannas, and Shrublands | - | - | - | - | 2 | 2 |
| Flooded Grasslands and Savannas | - | - | - | - | 1 | 1 |
| Montane Grasslands and Shrublands | 9 | 3 | - | 4 | 3 | 19 |
| Mediterranean Forests, Woodlands, and Scrub | 20 | 2 | - | 1 | 1 | 24 |
| Deserts and Xeric Shrublands | 3 | - | 1 | 2 | 4 | 10 |
| Mangroves | 1 | - | - | - | - | 1 |
| Wetlands | 2 | 1 | 1 | - | - | 4 |

**Table 3.** Extent of restorative activities within the projects, summarized for each restoration initiative.

| Restoration Initiative | Extent of Restorative Activities (ha) | | | | | | |
|---|---|---|---|---|---|---|---|
| | <1000 | 1000–5000 | 5000–20,000 | 20,000–100,000 | >100,000 | N/A | Total projects |
| **20 × 20** | 33 | 10 | 2 | 5 | 6 | | 56 |
| **GEF** | 0 | 0 | 1 | 5 | 11 | 1 | 18 |
| **FIP** | 0 | 1 | 0 | 1 | 9 | 3 | 14 |
| **CDM** | 7 | 6 | 5 | 1 | 0 | | 19 |
| **local** | 43 | 2 | 1 | 0 | 1 | | 47 |
| **Total** | 83 | 19 | 9 | 13 | 26 | 4 | 154 |

*3.2. Project Goals and Restorative Activities*

Projects generally pursue multiple goals and the goal to increase vegetation cover is the most common (117 projects) (Figure 2). All projects from GEF and CDM have this goal, while for the other initiatives increasing vegetation cover is important but not explicitly pursued by all projects. Evidently, linked to this goal, biodiversity recovery (105 projects) and recovery of ecological processes (100 projects) are also in the top 3 of most mentioned goals. Furthermore, many projects aim to provide

local employment and to improve the livelihoods of people, and many projects aim for climate change mitigation. Both goals were often pursued by projects from FIP, CDM and GEF. However, these goals occurred less in projects linked to Initiative 20 × 20 and local initiatives. Implementing agro-forestry or silvo-pastoral systems is a goal for many GEF and FIP projects, but occurs less for the other types of initiatives.
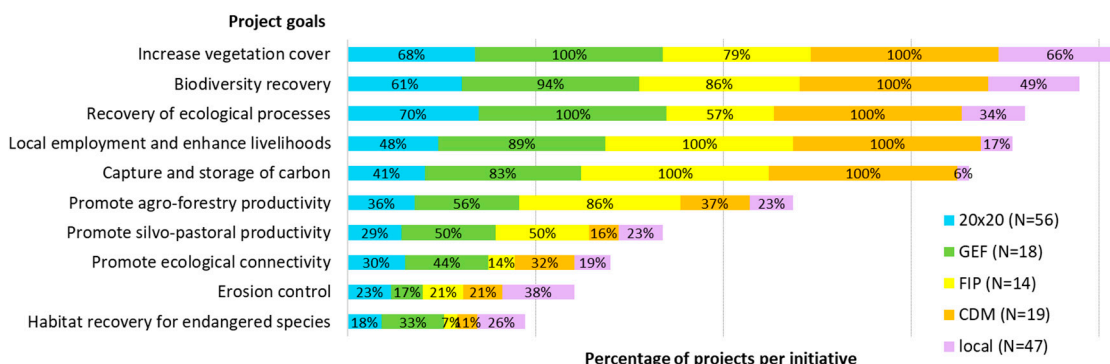


**Figure 2.** Overview of project goals. The 10 goals (out of 16) that occurred most are presented. The bars in the figure indicate the percentage of projects per restoration initiative that have a particular goal in their restoration strategy. One restoration project can have multiple goals. The total number of projects analysed was 154. Note: an earlier version of this figure was previously published as Figure 15.3 in Verchot et al. [41].

The main activity in all projects was "restoration of vegetation in terrestrial systems" (Table 4). This occurred in 95% of all projects (146 out of 154 projects). The main sub-activity under this activity was natural regeneration, which occurred in 53% of all projects, followed by assisted regeneration (32%) and mixed plantation with only trees (27%). Exclusion of grazing and adapting grazing pressure, sub-activity under "Control of barriers", was used in half of all projects. Erosion control, sub-activity under "Civil works", took place in one third of the projects. Restoration of vegetation in aquatic systems (12%) and restoration of fauna (13%) were the least used approaches.

**Table 4.** Overview of project activities. The table shows the percentage of projects that implement a certain restorative activity and/or sub-activity. Within one project multiple activities and multiple sub-activities can take place per category. The total number of projects analysed was 154.

| Restorative Activities | Restorative Sub-Activities | Percentage of Projects |
|---|---|---|
| **Civil works** | | **44%** |
| | Stabilization of the land, restoration of soil profiles | 19% |
| | Erosion control | 33% |
| **Control of regeneration barriers** | | **62%** |
| | Exclusion of grazing/adapting grazing pressure | 51% |
| | Restoration of fire regime, control of fires or controlled burning | 16% |
| | Herbicide application or grazing | 5% |
| | Fertilization | 18% |
| | Bioremediation to remove toxicity from soil or water | 1% |
| | Contaminant control | 5% |
| **Restoration of vegetation in terrestrial systems** | | **95%** |
| | Natural Regeneration | 53% |
| | Assisted regeneration | 32% |
| | Mixed plantation with only trees | 27% |
| | Plantation with mixture of trees, shrubs and grasses | 23% |
| | Monoculture plantation | 19% |

**Table 4.** *Cont.*

| Restorative Activities | Restorative Sub-Activities | Percentage of Projects |
|---|---|---|
| **Restoration of vegetation in aquatic systems** | | **12%** |
| | Natural succession | 8% |
| | Sowing of plant species | 5% |
| | Transfer of sludge | 2% |
| **Restoration of fauna** | | **13%** |
| | Establishment of structures to facilitate colonization | 13% |
| | Translocation of individuals from other places | 1% |

Table 5 shows that GEF and FIP projects are clearly differentiated from the rest as they mostly use natural regeneration within their projects. Assisted regeneration is also applied frequently within FIP projects, and in around half of the GEF projects. FIP projects sometimes use plantations within their restoration strategies, but plantations are most often used within CDM projects. In fact, CDM projects always included one or more types of forest plantation. Most often this concerned monoculture plantations, but other (mixed) types of plantations occurred as well. Projects associated with Initiative 20 × 20 are diverse and included all types of activities. In local projects, natural regeneration was the most common, followed by plantations with a mixture of trees, shrubs and grasses and mixed-trees plantations.

**Table 5.** Sub-activities under "Restoration of vegetation in terrestrial systems", summarized by restoration initiative. Note: one restoration project can have multiple restorative activities.

| Restoration Initiative | Natural Regeneration | Assisted Regeneration | Plantation: Monoculture | Plantation: Mixed Trees | Plantation: Mixed Trees, Shrubs, Grasses | Total Projects |
|---|---|---|---|---|---|---|
| **20 × 20** | 36% | 25% | 14% | 34% | 20% | 56 |
| **GEF** | 89% | 56% | 0% | 6% | 6% | 18 |
| **FIP** | 93% | 93% | 21% | 7% | 21% | 14 |
| **CDM** | 11% | 32% | 68% | 42% | 26% | 19 |
| **local** | 64% | 15% | 11% | 28% | 32% | 47 |

For some projects biodiversity recovery is the primary goal and for others this is a goal alongside other goals, such as to increase vegetation cover or to mitigate climate change. Another way of looking at biodiversity objectives is to investigate which type of plantations projects establish and whether they use exotic or native species. From Figure 3 it becomes apparent that exotic species, such as fast growing Eucalyptus and Acacia, were most often used in monoculture plantations (22 projects). This happened regularly in CDM projects (12 projects in total). Also, in other types of plantations established under CDM, exotic species were often planted. The plantations in projects related to Initiative 20 × 20 mostly used native species, but exotic species were sometimes used in the mixed plantations (7 projects) and monoculture plantations (4 projects). The plantations from the local projects mostly included native species.

*3.3. Potential Project Impact on Climate Change Mitigation*

Figure 1 (see Section 3.1) shows that many projects are located in areas with high biomass restoration potential. The degraded and deforested edges of the Amazon forest are prone to clearcutting or logging activities and because it mainly concerns tropical and sub-tropical moist broadleaf forests, which naturally contain a high amount of carbon; these areas can potentially accumulate a large amount of forest biomass when they are restored (>80 Mg forest AGB/ha). Similarly, there is high potential for additional forest AGB in the tropical forest biomes in the Southeast of Brazil and in parts of Central America. The two inset maps in Figure 1 show in more detail where the restoration projects are located

in parts of Colombia and Chile. Most of these projects are located in areas that have high potential to store additional forest AGB. Some caution is needed, however, on the potential for natural regeneration since climatic conditions and fire regimes are changing in the region and not all areas will be able to naturally and without assistance recover natural forests.
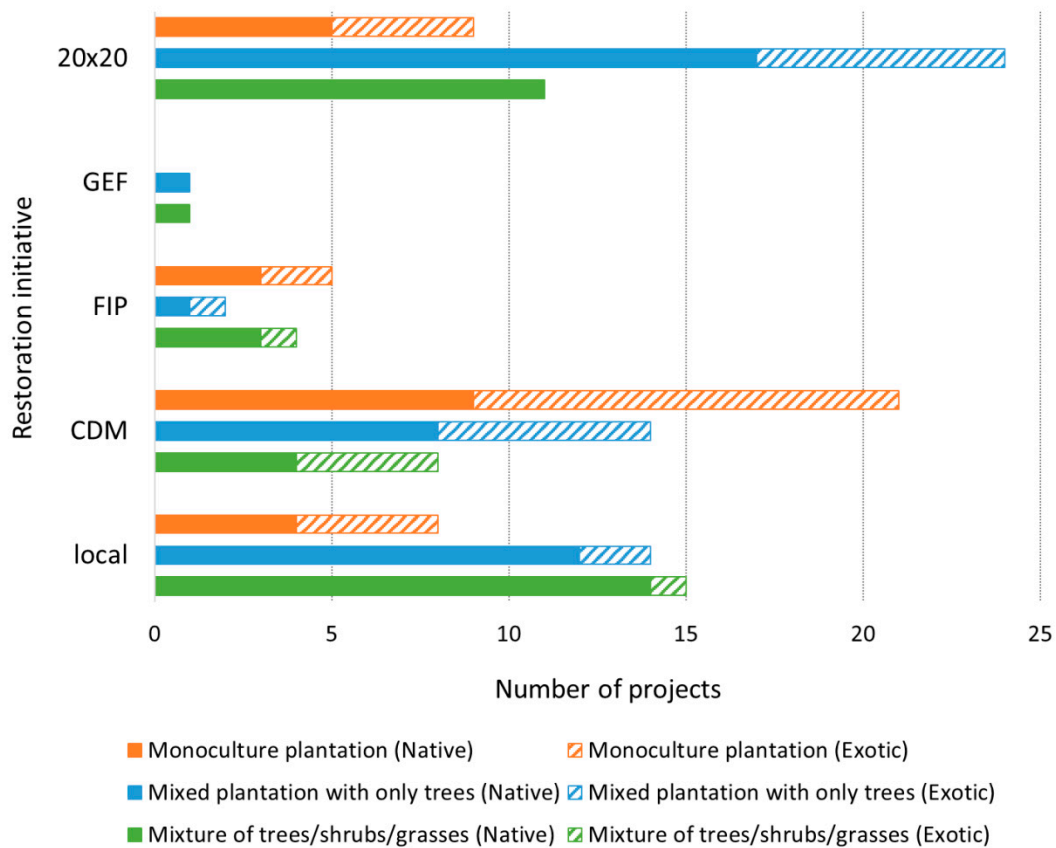


**Figure 3.** Number of projects that use a certain type of plantation (monoculture, mixed with only trees, mixture of trees/shrubs/grasses), with sub-division in type of species (native, exotic) used by the projects from different initiatives. Note: multiple plantations can take place within one project and one plantation can include exotic and/or native species. Therefore the total number of plantations displayed in the figure can exceed the total number of projects per initiative.

The map also shows areas where there is large potential for additional forest AGB, but where no projects are being implemented currently. Projects in these areas would have high potential for climate change mitigation. The white areas in the map are not covered by forests and/or do not have potential to become forests. Projects in these predominantly mountainous areas aim to restore shrublands, grasslands and steppes.

Figure 4 shows the relation between the current forest AGB and the potential of the project areas to store additional forest AGB for each initiative, when project areas would be restored to their potential forest coverage under a fragmented/managed condition. The boxplot shows that projects related to initiative $20 \times 20$ are located in areas where there is currently a high forest AGB, with a mean value of 187 Mg/ha, and, compared to the other initiatives, somewhat lower potential to accumulate forest AGB (mean value of 43 Mg/ha). The CDM and FIP projects are located in areas where there is relatively high mean forest AGB (123 and 120 Mg/ha respectively), and also somewhat higher potential to store more forest AGB (mean values of 50 and 49 Mg/ha). Projects under the GEF initiative and local projects have a lower average forest AGB (93 and 102 Mg/ha respectively). GEF projects have lowest potential to store additional forest AGB (mean value of 39 Mg/ha), while local projects have higher potential to store additional forest AGB (mean value of 50 Mg/ha). In summary, these results show that mitigation

potentials could be increased by 23% (for initiative 20 × 20) to 48% (for local projects) above current levels if degraded lands were restored to their potential forest state.
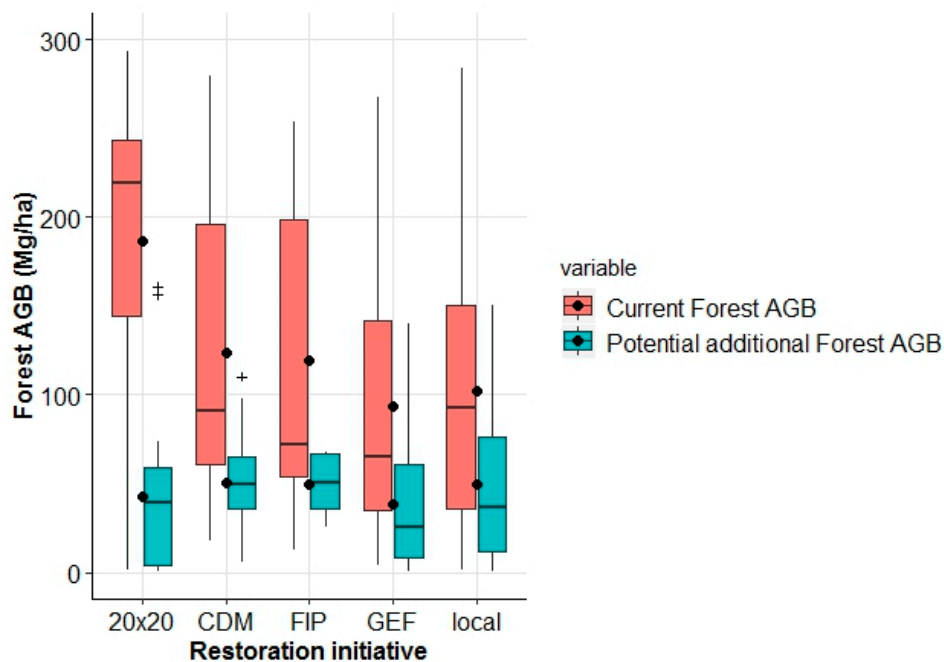


**Figure 4.** Current forest AGB (Mg/ha), in relation to the potential additional forest AGB, for each type of initiative. Note: the dot represents the mean; the horizontal bar represents the median, the + represents outliers, and the vertical line represents the range in which 95% of the values for all projects per initiative occur.

Some caution has to be taken when interpreting the mean current forest AGB and additional forest AGB values for the initiatives. We mapped project boundaries based on available geographical information. However, the actual restorative activities may take place in a smaller area within such a region. Consequently, when overlaying the project boundaries on different maps, values were summarized over the entire area, and thus also may include areas where no activities are taking place. This influenced the results and is also a cause for higher standard deviations. However, the results may still reveal a general picture of the mitigation potential situation within the project areas.

## 4. Discussion

Learning from current restoration initiatives in LAC and having an overview of the differences in goals, strategies and activities of implemented projects by the various initiatives is important as this could provide useful insights for scaling up of restoration activities. Our analysis shows that projects under the 5 different initiatives contribute to restoring degraded lands and towards achieving the Bonn Challenge goals in different ways. This means that there is no single means to implement restorative activities and that the diversity of projects and initiatives with the broad range of ecosystem management activities will lead towards achieving the aims of the Bonn Challenge and returning degraded land into sustainable landscapes that benefit the environment, people and the climate.

The five different initiatives share many common goals, but the approaches that they take to reach these goals differ, leading to a diversity in restorative activities on the ground. From our analysis we can conclude that each restoration initiative has its own "niche", in terms of project size, restorative activities and goals they pursue. This is illustrated below:

- GEF's approach to implement sustainable land management to minimize land degradation and to rehabilitate degraded areas is reflected by the project activities which entail natural

and assisted regeneration, implemented over large areas, rather than reforestation activities. Natural regeneration can be a cost-effective and efficient tool for large scale forest and landscape restoration in tropical regions [42]. Forests that naturally regenerate contribute to improving local biodiversity and biotic interactions and encourage native species to regrow, which enhances ecosystem resilience [8,42,43]. Moreover, natural regeneration of degraded forest areas has the potential to sequester high amounts of carbon [9]. Agroforestry and silvo-pastoral systems were often used as well; these approaches also enhance soil protection, increase vegetation cover and biodiversity, and increase farmers' income. Our analysis shows that GEF projects operate in forests with a relatively low current forest AGB, and somewhat lower potential to accumulate forest AGB than the other initiatives.

- The goals of the FIP programme to support REDD+ implementation are reflected in the FIP projects analysed, where all projects have the goal to capture and store carbon and to provide local employment and enhance livelihoods of forest dependent people. Linked to this, most projects are aimed at increasing vegetation cover and enhancing biodiversity recovery. The main activities to achieve these goals were natural regeneration and assisted regeneration, implemented over large areas. Similar to projects from GEF, FIP projects often used agroforestry and silvo-pastoral systems as approaches to recover degraded lands, to provide local employment and increase farmers' income. Our analysis showed that FIP projects are located in areas with relatively high potential to accumulate forest AGB (49 Mg/ha), which could indicate that FIP projects target the areas that are important for REDD+ implementation.

- The program objectives of the CDM include capturing and storing $CO_2$ in forests and providing job opportunities for local communities [27]. We observed indeed that all CDM projects had as core activity to establish forest plantations in relatively small areas. Projects often implemented multiple types of plantations, using both exotic and native species in their plantation schemes. All CDM projects mentioned that they aimed at recovering biodiversity, albeit not as primary goal, but as an environmental benefit from the fact that they are using native species. The value of plantation forests for biodiversity is still a topic of discussion. Various studies showed that plantation forests, even when they consist of exotic species, can increase regional levels of biodiversity, especially when they are planted on degraded lands [43–45]. However, they cannot replace the biodiversity values and species richness of primary forests. Mixing different types of tree species and using native trees, or an understorey with native shrubs would be more favourable [43–45]. Therefore, it can be questioned if CDM projects should be considered restorative or counted as activities under FLR. CDM projects are certainly aimed at enhancing human well-being by providing local employment, one of the core principles of FLR [12]. Whether these projects contribute to regaining ecological functionality of the landscape by planting monocultures in some cases remains uncertain. CDM projects are located in areas where there is currently relatively low forest AGB and a relatively high potential to store additional forest AGB. Therefore, the locations of CDM projects seem to be well selected to achieve the goal to store carbon and mitigate climate change by planting large numbers of trees.

- Initiative 20 × 20 was officially launched in 2014 at the COP in Lima, making this the youngest initiative that we investigated. Most projects in our database associated with this initiative aim to increase vegetation cover, to recover biodiversity, to recover ecological processes, to capture and store carbon and to generate local employment, through an FLR approach. Investments primarily come from the private sector, with an expectation of some kind of return from wood and non-wood forest products, ecotourism, agricultural products, avoided food security costs and carbon sequestration [46]. This was also reflected by the type of activities that occur in these projects, as economic activities such as agroforestry and silvo-pastoral systems and several types of plantations often occurred. Projects associated with Initiative 20 × 20 take place in high carbon forests, while the potential to store additional forest AGB was somewhat lower than for the other initiatives.

- Our last group of local, small-scale projects has diverging goals and activities. This is not surprising, as this group includes projects that are funded by various types of national and international donors and (sub) national governments. This variety in funding sources leads to a variety in goals and activities. Most projects aim at increasing vegetation cover and recovering biodiversity. Natural regeneration is the most used approach in these projects, while eliminating exotic species and erosion control are important activities too. When projects establish a plantation, the more natural types of plantations are favoured, using native species and mixing different types of trees or having a mix of trees, shrubs and grasses. Having considerable diversity in activities, but no emphasis on increasing local employment, these projects seem to target the local (ecological) problems and do not directly aim for economic benefit. On average, local projects have relatively high potential to store additional forest AGB (50 Mg/ha), and therefore restorative activities can potentially contribute to mitigating climate change in these project areas. As our group of local projects is not a representative sample (as explained in the methodology), it is impossible to determine whether there is a bias in the local category as the approach for collecting data is likely missed many small initiatives.

In summary, the differences in approaches taken by the 5 different initiatives imply that the donors and funding mechanisms that provide financing for the projects have a large influence on the restoration goals and restorative activities to implement. This seems self-evident as donor organizations and other funding mechanisms that support restoration projects originate from different global conventions and agreements, or local land policies, all with their own general purpose and strategies. Natural regeneration has more potential to store $CO_2$ than plantations or agroforestry and silvo-pastoral systems [14]. Moreover, naturally regenerated forests contribute more to restoring ecological processes and biodiversity than tree plantations [47,48]. Therefore, the restorative activities from GEF and FIP in general and from many projects from local initiatives and some projects from Initiative 20 × 20 may contribute largely to mitigating climate change. CDM projects were established with the primary goal to sequester carbon. As CDM projects use (monoculture) plantations, this seems to be the best means for rapid carbon accumulation on degraded sites. However, these plantations are being harvested from time to time, and therefore, the net benefit for climate change mitigation may be less effective in this type of projects than it seems at first hand [14]. Other goals such as providing employment and generating income for local people predominate in this initiative. For achieving the Bonn Challenge goals and the goals from the multiple global conventions, compromises are needed. FLR, implemented through a landscape approach thereby benefiting both the natural environment and the local people can contribute to achieving these goals, and the broad diversity of initiatives, with their own focal areas, seems to benefit this process.

Dryland biomes such as Mediterranean areas, deserts and xeric shrublands seem to be underrepresented in our analysis with only 25%. Dryland biomes are under pressure due to desertification, biodiversity loss, poverty, food insecurity and climate change and have high potential for implementing FLR which could have a positive contribution to sustainable development [49,50]. Our map with potential additional forest biomass could be useful for indicating the degraded areas within the dryland biomes with potential for restoration, but where currently no restoration projects are registered. When restored to their potential state, these areas could potentially accumulate (forest) biomass and thereby contribute to mitigating climate change.

For the map of potential additional forest AGB that we created for entire LAC (Figure 1) we followed a simple approach. We are aware of the caveats that are caused by using the different input datasets, especially the Atlas of Forest Landscape Restoration Opportunities from WRI. Our map is simply based on the information on potential forest coverage (See Table S3 in Supporting Information) to calculate future restoration potential. However, we think that our map gives a general idea of how much AGB could be stored again if degraded and deforested areas would be restored back to forests. It roughly outlines the areas with potential for restoration and shows that these are mainly located on the edges of the Amazon area. The map does not take into account harvest of plantations, nor does it

provide specific information on restoration strategies (e.g., plantations and natural regeneration) that could store most carbon. We only took into account the areas that are currently under agricultural land use and excluded these from the analysis (we expected these areas not to return to forests in the future).

## 5. Conclusions

In this paper we provided an overview of 154 planned, ongoing and finalized restoration projects in LAC and compared their characteristics (project size, goals, and restorative activities) with respect to the five different initiatives that the projects belong to. The goals of the different initiatives did not differ much; most common goals were to increase vegetation cover, to recover biodiversity and to recover ecological processes. Some differences could be observed for the goal to provide local employment and to enhance livelihoods and for the goal to capture and store carbon (both goals were mainly pursued by GEF, FIP and CDM). Most distinct differences could be observed for the restorative activities that projects under the 5 initiatives use. GEF and FIP mostly used natural and assisted regeneration over large areas, while CDM projects established plantations. Projects under Initiative 20 × 20 and local projects used a mix of different activities. This illustrates that there is no single best methodology, but that a diversity of projects and initiatives will contribute towards achieving the aims of the Bonn Challenge to restore large amounts of degraded land. In addition, our analysis showed that projects will contribute to climate change mitigation by storing additional forest AGB when deforested and degraded areas are restored to their potential forested state. However, the success of projects implemented within large-scale restoration initiatives depends on many factors. Identification of main drivers of deforestation and forest degradation and assessment of ecological conditions, social-cultural dynamics and other enabling factors (policies, laws and regulations) are important first steps. Integrated land-use planning, including effective intersectoral cooperation and coordination, thereby engaging all relevant stakeholder groups (including local communities) in planning and decision making are necessary processes [20]. For measuring the effectiveness of implemented activities, a monitoring baseline needs to be established and measurable indicators need to be defined. Once the success of a restoration project and the effectiveness of activities are quantified, lessons learnt for upscaling can be extracted. For example, for locally-adapted FLR activities, scaling up would benefit from describing the characteristics (biophysical, economic, social, legal) of successful smaller projects which could then be replicated in other similar areas and conditions. This would also assume that there may be an optimized restorative activity for different biomes, degradation types, funding amounts, and social contexts, that could help implement large-scale restoration visions [51]. Our study did not provide enough information to make recommendations for scaling up of activities in LAC as we did not assess the performance and success of projects. These are important themes for further research and necessary steps for meeting the Bonn challenge requirements for restoration of degraded lands and other commitments under SDG goal 15 and the CBD Aichi target.

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