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LETTER

What is out there? a typology of land restoration projects in Latin America and the Caribbean

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Abstract

Restoring degraded lands is high on the international agenda and the number of restoration projects in Latin America and the Caribbean (LAC) has increased considerably over the past decades. However, the variety of approaches used have not been systematically documented and analyzed. We aimed to develop a restoration typology as a function of the geographical and socio-economical setting, planning, timeframe, finances, implementation, monitoring and potential impact, which will help to discern broad patterns and identify gaps in project implementation in LAC. We categorized 97 restoration projects using Multiple Correspondence Analysis and a Hierarchical Clustering on Principal Components. Three main restoration types emerged from the clustering, with the main defining variables being: (1) project area under restoration, (2) amount of funding received, (3) source of funding and (4) monitoring efforts. The first type are large-scale projects, which receive high amounts of funding provided by international donors, and with a well-established monitoring plan; the second type are projects financed with private money, typically lacking a sound monitoring program; and the third type represents small projects with low amounts of funding, financed with public funds from national governments, often with a rudimentary monitoring plan. The typology enables a comparative analysis of the status and trends of restoration activities across Latin America. We conclude that, despite growing awareness and recognition that integrated approaches are needed to revert complex and interconnected socio-economic and environmental issues like land degradation, the socio-economic dimension remains underexposed in the majority of restoration projects, whereas monitoring is still regarded as an extra cost instead of a necessary investment.

1. Introduction

Land degradation is a growing global problem resulting in annual losses between 6.2 and 10.3 trillion US dollars (ELD 2015) and affecting at least 1.6 billion people worldwide (Bai *et al* 2008). Restoring degraded lands is urgently needed to protect biodiversity and ecosystem services, and to halt and reverse land degradation (IPBES 2018), and is high on the international agenda, e.g. Aichi Biodiversity Target 15 (CBD 2011), Bonn

Challenge (IUCN 2011), the New York Declaration on Forests (UN 2014) and Sustainable Development Goal 15 (UN 2015).

At the ecosystem level the Society of Ecological Restoration (SER) distinguishes three groups of restorative activities (McDonald *et al* 2016): *Ecological restoration* aims at the complete recovery of the ecological functions and processes, and the biotic community structure of the original ecosystem. *Rehabilitation* strives to repair key ecosystem functions, processes and services not necessarily leading to a complete recovery of the original ecosystem and reclamation is limited to repairing only minimal functions of the land. When restoration is applied at the landscape scale it is referred to as forest landscape restoration (FLR) which is a holistic approach that aims to regain ecological functionality and enhance human well-being across deforested or degraded landscapes (Sabogal *et al* 2015, GPFLR 2018). FLR may include all three types of restorative activities abovementioned as they are applied to different ecosystems within a landscape. Even though the focus of FLR is human wellbeing, a sustainable FLR project requires a balance between natural and productive systems, because productive systems and humans depend on the natural ecosystems as well. Therefore, in a FLR project, one could be *restoring* natural ecosystems in some areas, and ensuring they have a full complement of native species, *rehabilitating* land for agricultural productivity in other areas, and *reclaiming* areas where e.g. only mineral soil remains. In essence, FLR is a deliberate intervention where a suite of different land uses, varying from natural forest cover to commercial plantations, natural and assisted regeneration, and agroforestry and silvo-pastoral systems, coexist within a 'multifunctional landscape' (Laestadius *et al* 2015, Aronson *et al* 2017). In this paper, we will use the term restoration in a broad sense, referring to both ecological restoration and FLR.

The stiff competition between land used for agriculture and demands for conservation of biodiversity and provision of ecosystem services is evident in Latin American and the Caribbean (LAC) (Harvey *et al* 2008, Estrada-Carmona *et al* 2014). The LAC region not only contains seven of the 25 biodiversity hotspots worldwide (Myers *et al* 2000) but also one of the four main global AFOLU (Agriculture, Forestry and Other Land Uses) emission hotspots (de Sy *et al* 2015, Roman-Cuesta *et al* 2016). Restoration is likely to increase biodiversity (Rey Benayas *et al* 2009) and has great potential for carbon sequestration (Chazdon *et al* 2016). Furthermore, restoring degraded agricultural lands to increase agricultural production can contribute to meeting growing global food demands, diminishing pressure on undisturbed ecosystems by agricultural expansion, and improving rural livelihoods (Lamb *et al* 2005, Sayer *et al* 2013).

The multiple benefits of restoration and the growing awareness that sectoral approaches are not suitable for complex and interconnected socio-economic and environmental issues (Reed *et al* 2016) have led to a significant increase in both the design and implementation of projects and initiatives worldwide. As a response to the Bonn Challenge, seventeen national governments, three subnational government and three non-governmental organizations in LAC have committed, to date, to restore about 53 million hectares of land under Initiative 20 × 20 while other programs that target climate change mitigation such as the Forest Investment Program (FIP) or the Global Environmental Facility (GEF) have similarly adopted restoration as an entry point to sustainably manage natural resources (GEF 2018).

Given the multiple objectives of restoration to satisfy environmental and socioeconomic goals and the millions of hectares of land committed to undergo restoration so far, a typology of restoration projects may help to discern broad patterns and identify gaps in project implementation in LAC. Although others have carried out assessments of ecological restoration projects at the national level (Murcia and Guariguata 2014, Cerrón *et al* 2017, Méndez-Toribio *et al* 2018) and of integrated landscape initiatives at the regional level (Estrada-Carmona *et al* 2014), a multidimensional assessment is lacking. That said, we developed a typology of restoration projects in LAC as a function of socio-environmental settings, planning, timeframe, finances, implementation, monitoring and potential impact, using multivariate techniques. The typology enables a comparative analysis to provide insights on what is happening on the ground.

Restoration projects are complex. Their successful implementation requires careful project planning to minimize conflicts of interests and strike a balance among the multiple functions of a landscape and all relevant stakeholders (Sayer *et al* 2013, Meli *et al* 2016, Murcia *et al* 2016). Also, clarity about land tenure and rights (Duchelle *et al* 2014, Ceccon *et al* 2015), and understanding and addressing the drivers of degradation are essential for the long-term sustainability of interventions (Crouzeilles *et al* 2016, Brancalion *et al* 2016). Finally, an objective-based monitoring plan grounded on a baseline assessment is required to provide evidence on the socio-economic and environmental benefits (Hobbs and Norton 1996, Chazdon 2008, Evans *et al* 2018). Monitoring also allows for improving best practices (Holl and Aide 2011, Suding 2011), adaptive management (IUCN and WRI 2014), long-term evaluation of different approaches (Chazdon and Guariguata 2016, Meli *et al* 2017) and measuring the socio-economic and environmental impact of the project (Adams *et al* 2016, Aronson *et al* 2010).

In this paper we focus on recently finished, ongoing and pledged restoration projects in LAC and we aim to provide a coherent overview of how these projects are, in practice, contributing to satisfying multiple goals. This knowledge is urgently needed to guide and improve efforts to up- and outscale restoration practices (Estrada-

Carmona *et al* 2014, Murcia *et al* 2016). Accordingly, our first objective is to define a typology of restoration activities based on the variables related to socio-environmental settings, planning, timeframe, finances, implementation, monitoring and potential impact. The second objective is to evaluate gaps in each restoration type through comparative analysis.

2. Materials and methods

2.1. Selection of projects and variables

We selected 97 restoration projects that started in 2000 or later, with the majority starting after 2008, and covered areas of at least 10 ha from a previously assembled database of projects carried out across LAC by multilateral donors, national and sub-national governments, and NGOs (Romijn and Coppus 2019, Open Access). For more information about the compilation of the database, see Supporting Information. The multilateral projects were financed by the Global Environment Facility (GEF), that supports countries to develop and implement biodiversity, and climate change adaptation and mitigation strategies (GEF 2018), or the Forestry Investment Program (FIP), which addresses the drivers of deforestation and forest degradation to achieve REDD + objectives. For private sector/NGO projects associated with Initiative 20 × 20, the World Resources Institute (WRI) provided descriptions of projects. We selected projects from two restoration databases for Colombia (Murcia and Guariguata 2014) and Mexico (Méndez-Toribio *et al* 2018) compiled by the Centre for International Forestry Research (CIFOR). We also used projects from a database compiled by Bioversity International, the World Agroforestry Centre (ICRAF) and Servicio Forestal Nacional y de Fauna Silvestre (SERFOR) for Peru (Cerrón *et al* 2017).

The list of variables and categories used for this study was adopted from the national inventories in Colombia, Peru and Mexico (Murcia and Guariguata 2014, Cerrón *et al* 2017, Méndez-Toribio *et al* 2018) and adjusted to fit the regional scope of this study (table 1). The variables were grouped into classes that reflect the socio-economic, biophysical, organizational, technical and financial aspects of restoration projects. The variables were divided into categories. In general, the categories were not mutually exclusive, which means that a combination of categories can represent a variable. All categories were represented by two or more levels. The levels of the non mutually exclusive categories were 0 if absent, 1 if present or NA when missing, whereas the levels of the mutually exclusive categories corresponded with ordinal integer values. For example, the variable land use prior to restoration could consist of the categories agriculture, grazing and forestry whereas the category levels of the variable project area varied from 1 (<50 ha) to 8 (>100,000 ha) (table 1).

To minimize the amount of missing data affecting the multivariate analyses, we combined categories to the extent possible. Both projects with missing values for more than four categories, and categories with more than 50% missing values were excluded from the multivariate analyses. For more information on the variables and categories included, see Supporting Information.

2.2. Multivariate analysis

To define a typology of restoration activities, we used Multiple Correspondence Analysis (MCA) followed by a Hierarchical Clustering on Principal Components (HCPC). MCA is an exploratory technique to analyze correspondence in a multi-way frequency table (Bartholomew *et al* 2008) and illustrates the most important relationships among the variable´s response categories in a graphical way (Sourial *et al* 2010). The MCA was run with the FactoMineR package (Lê *et al* 2008) using R software (R Core Team 2016). In the resulting biplot inferences can be made of the relative associations between projects and levels. Only levels with a contribution to the definition of the particular dimension higher than 1% and a $\cos^2$ (its quality of representation) higher than 0.2 were used to define restoration types (see supporting information Multivariate analyses and table S1 is available online at stacks.iop.org/ERC/1/041004/mmedia).

The first 20 dimensions of the MCA, which together explained 61% of the variance in the dataset, were used in a Hierarchical Clustering on Principal Components (HCPC) to create groups of restoration projects that share similar characteristics, i.e. restoration types. The HCPC was run with the FactoMineR package (Lê *et al* 2008) which uses the Ward criterion as it is based on the multidimensional variance calculated in the MCA. The final partitioning was obtained with K-means clustering (Lê *et al* 2008). In the output of the HCPC the values of Mod/Cla and Cla/Mod provide information about the content of the clusters, where Mod refers to modality or category level and Cla is the class or cluster (Husson *et al* 2010). The column Mod/Cla shows the percentage of restoration projects in the cluster that meet the category level and can be interpreted as a measure of robustness of a cluster for the specific category level. The column Cla/Mod shows the percentage of all projects that meet the category level and belong to the specific cluster and can be interpreted as a measure of uniqueness of a specific category level for the cluster. For example, when the category improving livelihoods has a value of 100%

Table 1. Variables and categories used for the typology.

Class	Variable	Categories (levels)
Socio -environmental setting	Project area	Project area (1: <50 ha; 2: 51–100 ha; 3: 101–500 ha; 4: 501–1000 ha; 5: 1001–5000 ha; 6: 5001–20,000 ha; 7: 20,001–100,000 ha; 8: 100,001–100,000 ha; 9: NA)
	Biome (Olson *et al* 2001)	(sub)Tropical moist broadleaf forests; (sub)Tropical dry broadleaf forests; (sub)Tropical coniferous forests; Temperate broadleaf and mixed forests; (sub)Tropical grasslands, savannas, and shrublands; Temperate grasslands, savannas, and shrublands; Flooded grasslands and savannas; Montane grasslands and shrublands; Mediterranean forests, woodlands, and scrubs; Deserts and xeric shrublands; Mangroves; Wetlands
	Land tenure	Smallholders; Large properties; Public; Community
	Land use prior to restoration	Mining; Agriculture; Grazing; Forestry; Agro-silvo-pastoral system; Secondary or slightly intervened forest; Abandoned; Original ecosystem not subject to extraction
	Drivers of land use change	Opencast mining or extraction of materials; Erosion/landslides, not associated with extraction; Contamination of the substrate or environment; Extensive and recurrent burning; Large-scale disturbance due to extreme events; Overgrazing; Unsustainable agricultural practices; Recent logging for wood, grazing land or agriculture; Urban or sub-urban use; Fuel wood collection/charcoal production
Planning	Objectives	Improve vegetation cover; Biodiversity recovery; Habitat recovery for endangered species; Promote ecological connectivity in fragmented habitats; Recovery of ecological processes - restore the structure, function, and ecosystem services; Elimination of exotic/invasive or unwanted species; Erosion control; Reducing risks (e.g., bioengineering in gullies or slopes, mitigation of coastal erosion, decontamination); Reclamation, repair of an ecosystem after extraction of minerals; Restoration of cultural and spiritual values; Generation of local employment and enhance livelihoods; Capture and storage of carbon; Promote silvo-pastoral productivity; Promote agro-forestry productivity; Recreation/eco-tourism; Comply with government mandate (decree, law)
	Degradation	Causes of degradation determined; Causes of degradation addressed; Degree of degradation determined
	Community participation	Community participation (1: None; 2: Active; 3: Passive; 4: NA)
	Government involvement	Government involvement
	Responsible implementing institute	Responsible implementing institute (1: Public institution; 2: NGO; 3: University; 4: Company; 5: Community; 6: Other; 7: Various institutes)
Timeframe	Project duration	Project duration (1: <1 yr; 2: 1–5 yr; 3: 6–10 yr; 4: 11–50 yr)
	State/current phase of the project	Phase (1: Planning; 2: In progress (field preparation, planting/implementation); 3: Actions finished without follow-up; 4: Actions finished and further monitoring; 5: NA)
Financial	Source of funding	National governments; National donors; International donors; Company/Owner of property; Community; Investor
	Amount of funding received	Amount in kUS$ (1: <500; 2: 501–1000; 3: 1001–2000 kS$; 4: 2001–5000 kUS$; 5: 5001–10,000 kUS$; 6: >10,000 kUS$; 7: NA)
	Economic Incentives	Payment ecosystem services; Carbon sequestration; Timber products; Non-timber products; Other
Intervention	Civil works	Stabilization of the land, restoration of soil profiles, or recovery of the river bed
	Control of barriers	Erosion control; Exclusion of grazers; Control of fire regime; Herbicide application or grazing; Fertilization; Contaminant control
	Restoration approach for terrestrial vegetation	Natural regeneration; Assisted regeneration; Regeneration unspecified; Mono plantation; Mixed plantation with only trees; Plantation with mixture of trees, shrubs and grasses; Plantation unspecified
	Restoration approach for aquatic vegetation	Natural succession in aquatic systems; Sowing of emerging plant species; Transfer of sludge in aquatic systems
	Restoration approach for fauna	Establishment of structures to facilitate colonization; Translocation of individuals from other places
	Origin of biological material	Exotic species; Native species
Monitoring	Monitoring planning	

Table 1. (Continued.)

Class	Variable	Categories (levels)
		Monitoring plan included; Baseline assessment; Relation with objectives
	Monitoring participation	Public institute; NGO; University; Company; Community; Other
Potential impact	Environmental Impact	Improving biodiversity; Management of hydrology; Addressing climate change
	Socio-Economic Impact	Improving food security; Capacity building of community; Improving livelihoods

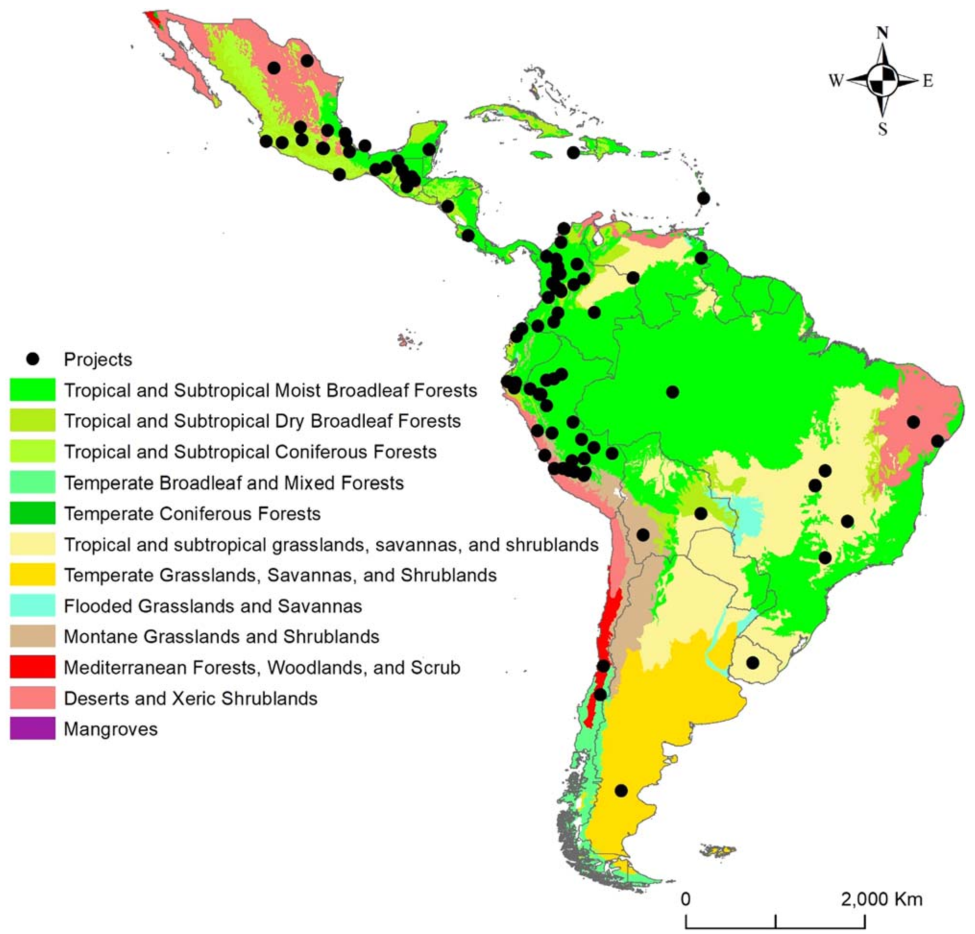

Figure 1. The geographical distribution of the 97 projects across the biomes (Olson *et al* 2001).

for Mod/Cla it means that 100% of the projects in the cluster comply with improving livelihoods. A value of 70% for Cla/Mod means that 70% of all projects that improve livelihoods, are in the cluster.

3. Results

3.1. Characterization of restoration projects

The projects included in the analysis were distributed over 15 countries in LAC and 11 biomes according to Olson *et al* (2001; figure 1). Half of the restoration projects covered areas smaller than 1,000 ha and 20% were larger than 100,000 ha (figure 2(a)). Pasture (67%) and agriculture (79%) were the most frequent types of land use reported at the onset of the restoration intervention. Secondary forest appeared in 47% of the projects and in 29% patches of the original ecosystem were still present (figure 2(b)). Objectives related to nature conservation guided nearly all projects (97%). Economic objectives (improvement of local employment and eco-tourism) and objectives related to alternative agricultural production systems (agro-forestry and silvo-pastoral systems) were mentioned for 60% and 63% of projects, respectively (figure 2(c)). Half of the projects were financed by national governments (52%) followed by international donors (46%) and impact investors (27%; figure 2(d)). In 31% of

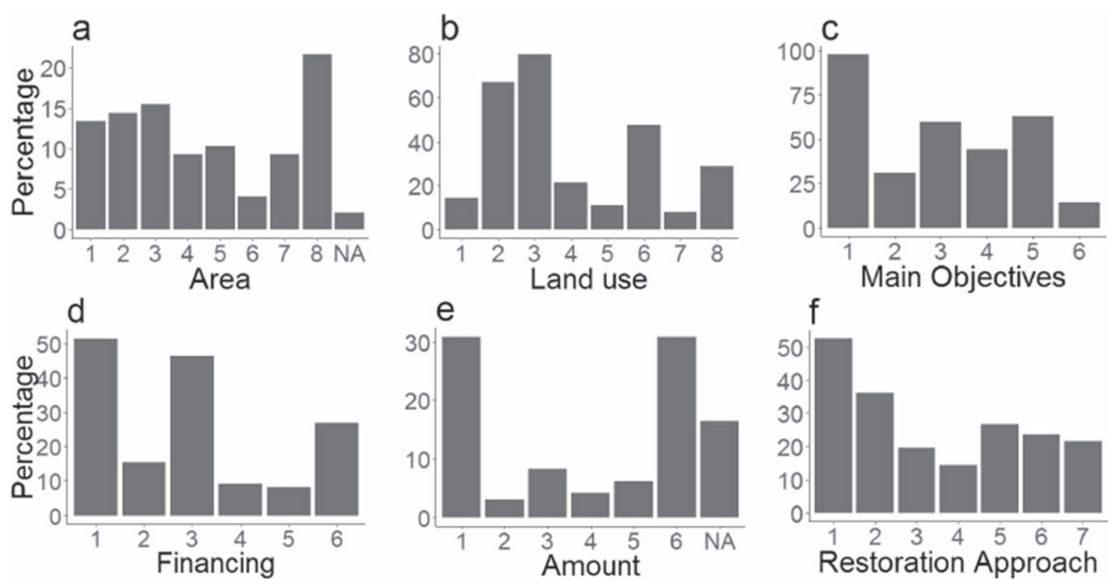

Figure 2. Relative frequency distribution of (a) project area, (b) land use prior to intervention, (c) main objectives (see supporting information), (d) sources of financing, (e) amount of funding received and (f) restoration approach for terrestrial vegetation, across all analyzed restoration projects. Project area (ha) 1: <50; 2: <100; 3 <500; 4: <1000; 5: <5000; 6: <20,000; 7: <100,000; 8: >100,000; NA. Land use 1: Mining; 2: Agriculture; 3: Pasture; 4: Forestry; 5: Agro-silvo-pastoral system; 6: Secondary or slightly intervened forest; 7: Abandoned; 8: Original ecosystem not subject to extraction. Main objectives 1: Nature conservation; 2: Erosion; 3: Economic; 4: Carbon sequestration; 5: Sustainable agricultural production systems; 6: Spiritual and cultural values. Financing type 1: National governments; 2: National donors; 3: International donors; 4: Company/Owner of property; 5: Community; 6: Investor. Amount of funding (in kUSD) 1: <500; 2: <1,000; 3: <2,000; 4: <5,000; 5: <10,000; 6: > 10,000; NA. Restoration approach 1: Natural regeneration; 2: Assisted regeneration; 3: Regeneration unspecified; 4: Mono plantation; 5: Mixed plantation with only trees; 6: Plantation with mixture of trees, shrubs and grasses; 7: Plantation unspecified.

the cases the amount of funding received were less than 500,000 US$ while 30% of the projects received funding of more than 10,000,000 US$ (figure 2(e)). In 16% of the projects the funding amounts were not mentioned. Natural regeneration of vegetation (53%) and assisted regeneration (36%) were the two most commonly used approaches (figure 2(f)). Twenty seven percent of the projects used mixed tree plantations.

3.2. Typology of restoration projects

On the basis of the MCA (figure 3), three clusters representing the restoration types, emerged from the HCPC. Type 1 (33 projects, 34%) is defined by funding by international donors, large project areas (>100,000 ha) and large amount of funding (>10,000,000 US$; figure 3 and table S1). The objectives of these projects included recovery of biodiversity, improvement of ecological processes, generation of local employment and the capture and storage of carbon. Areas with secondary forest and patches of the original ecosystem occurred within the project boundaries, and natural and assisted regeneration of vegetation were part of the implementation approaches (tables S1 and 2). All projects determined the causes and the degree of degradation, and undertook actions to address these drivers. The monitoring plans included a base line study and the variables monitored related to the objectives. Implementation and monitoring was mainly carried out by public institutions (figure 3). Projects were largely aimed at improving livelihoods, capacitation of local communities, regulating hydrologic processes and ensuring water availability, and addressing climate change by increasing C stocks in biomass and/or soils.

Financing by impact investors and timber products as economic revenue were the main determinants of type 2 (22 projects, 23%, figure 3 and table S1) and 78% of all projects financed by companies or private land owners were grouped in this cluster (table 2). The degree of degradation in the project areas was often not determined and many projects did not have a monitoring plan and did not carry out a baseline assessment. In general, the restoration approaches did not explicitly consider natural forest regeneration. Fifty-five percent of type 2 projects focused on mixed tree plantations (table 2).

Funding by national governments and relatively low costs (less than 500,000 US$) defined type 3 (42 projects, 43%, figure 3 and table S1). Most projects covering areas smaller than 100 ha belonged to this cluster (table 2). Sixty-two percent of the projects excluded grazers and 55% tried to improve ecological processes. Agroforestry production systems were not promoted and exotic species were generally not preferred in this type of restoration (table 2). Capture and storage of carbon was not an objective, carbon sequestration was not used as an economic incentive and neither addressing climate change nor improvement of livelihoods of communities

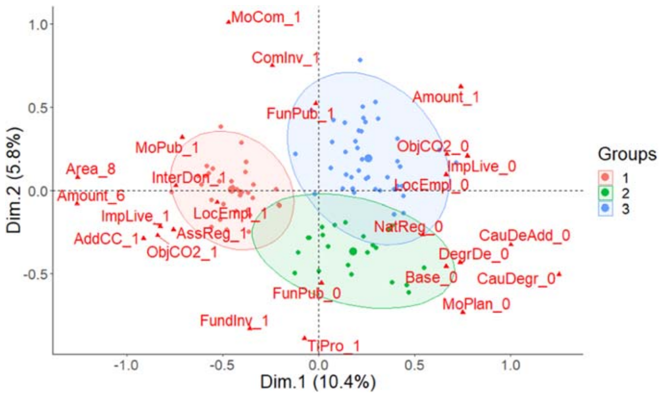

Figure 3. Biplot displaying the correlation between clusters (Groups) of restoration projects and selected categories (to improve readability, not all categories of table S1 are included). (0 = absence, 1 = presence, Area_8 = >100,000 ha; AddCC = Address climate change; AssReg = Assisted regeneration; CauDeAdd = Causes of degradation addressed; CauDegr = Causes of degradation determined; ComInv_1 = Active participation by communities; Amount_1 = <500,000 US$; Amount_6 = >10,000,000 US$; DegrDe = Degree of degradation determined; FundInv = Funding by investor; FunPub = Funding by public institute; InterDon = Funding by international donors; ImpLive = Improve livelihoods; LocEmpl = Generation of local employment; MoCom = Monitoring by community; MoPlan = Monitoring plan; MoPub = Monitoring by publIc institute; $ObjCO_2$ = Objective capture and storage of carbon; TiPro = Timber products.

Table 2. Categories that characterize the restoration type, categories in italics also appear in table S1. Mod/Cla is the % of projects per restoration type, Cla/Mod is the % of projects in the restoration type per overall occurrence of the category level (see section 2.2.).

Cluster	Category	Level	Mod/Cla (%)	Cla/Mod (%)
1	*Address climate change*	Yes	100	75
	Improve livelihood community	Yes	100	70
	Degree of degradation determined	Yes	100	54
	Causes of degradation addressed	Yes	100	45
	Capacity building of community	Yes	100	42
	Causes degradation determined	Yes	100	39
	Funding by International donors	Yes	97	71
	Monitoring plan	Yes	97	46
	Natural regeneration	Yes	94	61
	Objective recovery biodiversity	Yes	94	46
	Objective capture and storage of carbon	Yes	91	70
	Baseline included	Yes	91	57
	Objective recovery of ecological processes	Yes	88	45
	Amount of funding_6	*>10,000,000 USD*	85	93
	Generation of local employment	Yes	85	52
	Relation monitoring-objectives	Yes	85	47
	Management of hydrology	Yes	82	43
2	*Natural regeneration*	No	86	41
	Timber products	Yes	77	53
	Funding by investor	Yes	73	62
	Monitoring plan	No	73	57
	Degree of degradation determined	No	73	44
	Plantation with mixed trees	Yes	55	46
	Funding by company or private owner	Yes	32	78
3	*Funding by investor*	No	100	59
	Incentive Carbon Sequestration	No	95	49
	Objective carbon sequestration	No	93	72
	Assisted regeneration	No	90	61
	Promote agro forestry	No	81	64
	Exotic species	No	81	51
	Funding by pubic institute	*Yes*	69	58
	Intervention exclusion of grazers	Yes	62	55
	Objective recovery of ecological processes	Yes	55	36
	Project area	50–99 (ha)	29	86
	Project area	<50 (ha)	26	85

Table 3. Comparative analysis of the restoration types. The relative frequency distribution of categories per restoration type is shown with low referring to <50%, intermediate to 50%–75% and high to >75%.

		Restoration type		
Variable	Category	1	2	3
Community Involvement	Active	low	low	low
	Passive	interm.	interm.	low
Objectives	Multiple objectives	high	high	interm.
Degradation	Causes of degradation determined	high	high	high
	Causes of degradation addressed	high	Interm.	interm.
	Degree of degradation determined	high	low	interm.
Restoration approach for vegetation	Natural regeneration	high	low	low
	Assisted regeneration	interm.	low	low
	Mono plantation	low	low	low
	Mixed tree plantation	low	interm.	low
Species origin	Exotic species	low	low	low
	Native species	high	high	high
Monitoring planning	Monitoring plan	high	low	interm.
	Baseline study	high	low	low
	Relation with objectives	high	low	interm.
Economic incentives/revenues	Payment for ecosystem services	low	low	low
	Carbon sequestration	low	low	low
	Timber products	low	high	low
	Non timber products	interm.	interm.	low
	Other	low	low	low
Environmental Impact	Improving biodiversity	high	low	interm.
	Management of hydrology	high	low	interm.
	Mitigation climate change	high	low	low
Socio-Economic Impact	Improve food security	interm.	low	low
	Capacity building community	high	high	interm.
	Improve livelihood community	high	low	low

had priority (tables S1 and 2). Also active community involvement defined type 3 projects to a certain degree, although this association was less clear than for the other variables (figure 3).

Community monitoring, and the omission of determining and addressing the causes of degradation were not related to any specific type (figure 3 and table S1).

3.3. Comparative analysis of restoration types

Table 3 shows the relative frequency distribution of projects per restoration type for a selected set of categories (see SI Variables and categories). Although many projects were implemented on lands partially owned by smallholders (47%) and communities (54%), active community involvement was generally low (table 3). Passive involvement was between 38% and 64% but often in the form of hired local labor.

Addressing multiple objectives was a common feature in all restoration types and reflects the multi-functional aspect of restoration (table 3). The projects of type 1 had sound planning that addressed the causes of degradation. In contrast, projects grouped as type 2, despite having identified the main causes of degradation, often did not take actions against these causes and the degree of degradation was poorly understood.

Natural and assisted regeneration was the preferred implementation approach in projects funded by international donors (type 1) whereas impact investor projects (type 2) typically promoted mixed tree plantations (table 3). All types preferred the use of native species although exotic species were used in 41% of the projects financed with private money, which are mostly found in type 2.

The projects of type 1 had a coherent monitoring plan, which included a baseline study and in which variables to be monitored were related to the objectives of the restoration effort, contrary to the projects of type 2, where monitoring was often lacking (table 3).

The economic incentives and revenues of projects with funding from impact investors focused on timber and non-timber products, and to some extent carbon sequestration (41%). Payment for ecosystem services (PES) schemes were to a certain degree associated with funding from international donors (30% of the projects of type 3) but almost absent in the other types.

Apart from improving food security (58%), the environmental and socio-economic impact was of great importance to the international donor projects. Type 3 prioritized environmental benefits such as improving biodiversity and ensuring water availability, though to a lesser extent than type 1

4. Discussion and conclusions

The 97 projects analyzed for LAC fit into three general restoration types, which can be discerned based on four main variables: (1) project area under restoration, (2) amount of funding received, (3) source of funding and (4) monitoring efforts (table 4).

Our results show that projects of restoration type 1 follow country-level agendas and are aligned with international agreements such as the Convention on Biodiversity (CBD) and the Sustainable Development Goals. Projects allocated in type 2 operate at the local level and focus on the primary interests of impact investors and companies, i.e. making profit, with nature conservation as secondary objective. Restoration activities of type 3 focus on improving local environmental conditions and do not appear to be strongly linked with national policies to meet international commitments.

The results suggest that many restoration projects take a top—down approach, not necessarily considering the interests of communities. Apart from the international donors funded projects, few aimed at generating local employment and improving livelihoods. In addition, communities were often not consulted in the planning phase and their participation was mostly limited to the implementation phase. Rarely were local communities involved in monitoring or acting as main responsible. This is in line with the national restoration inventories of Colombia (Murcia and Guariguata 2014), Peru (Cerrón *et al* 2017) and Mexico (Méndez-Toribio *et al* 2018), and a regional assessment of integrated landscape initiatives in LAC (Estrada-Carmona *et al* 2014), which reported low active community involvement and showed that poverty alleviation efforts are not a priority in many projects.

Many projects financed by project investors were associated with Initiative 20 × 20 but the relation between national restoration projects and the initiative was less clear. Although the 20 × 20 projects seem to be disconnected from the national restoration agendas, it is very likely they will be used to demonstrate the countries efforts to meet their national restoration pledges. Projects that are dominantly financed with either private (type 2) or public funds (type 3) are complementary in the sense that they focus on economic and environmental benefits, respectively, and both operate at the local level. Combining both types of projects could create synergies if they are embedded in public-private-civic partnerships that adopt a landscape approach. Such partnerships are increasingly being promoted to meet commitments like the Bonn Challenge, the Aichi biodiversity targets, the New York Declaration on Forests, Initiative 20 × 20 and the Sustainable Development Goals (Pistorius and Freiberg 2014, Scherr *et al* 2017).

National and local governments should play a more active role in convening multi-stakeholder partnerships needed for out- and upscaling. However, large scale restoration programs cannot solely rely on top—down approaches as they often focus on short-time results and do not stimulate better practices, resulting in low involvement of the participating stakeholders, especially in regions with poor governance and weak legal enforcement (McConnachie *et al* 2013, Pinto *et al* 2014). Hence, appropriate legal instruments that encourage and foster bottom-up grassroots initiatives must be developed at the same time (Pinto *et al* 2014, Murcia *et al* 2016).

Despite repeated calls that decision makers and land managers need evidence-based assessments to evaluate the success of restoration efforts (e.g. Palmer and Filoso 2009, Menz *et al* 2013), in many projects monitoring is still being regarded as an extra cost rather than a necessary investment. Monitoring as an integral part of the restoration activity was only common in projects funded by international donors. Monitoring in projects financed with public funds often only included a limited number of biological indicators related to plant survival, growth and health (Murcia and Guariguata 2014, Cerrón *et al* 2017, Méndez-Toribio *et al* 2018). To improve monitoring, capacity strengthening of communities, which was a recurring component of most restoration projects, should be used for organizing participatory workshops to discuss with local stakeholders which indicators to monitor in a cost-effective way. Participatory monitoring would greatly increase active community involvement and strengthen collective ownership of the restoration activity (Danielsen *et al* 2011, Evens *et al* 2018).

Monospecific plantations make up only a small proportion of the applied restoration approaches in all types. Barlow *et al* (2007) and Lamb (2014) pointed out that monospecific plantations are not very likely to deliver multiple benefits such as sustainable livelihoods and improvement of ecosystem services, and it seems that this message has been internalized by international donors, impact investors and national governments. Moreover, in all restoration types preference was given to native species although in privately financed projects exotic species were used as well.

PES schemes were not frequently incorporated in restoration activities in LAC. This is probably due to uncertainties in the long-term sustainability of projects (Bullock *et al* 2011) and the limited effectiveness of PES in promoting forest restoration (Pirard *et al* 2014). Also, PES schemes tend to be more efficient when a single, clearly defined ecosystem service is targeted (Wunder *et al* 2008) which is often not the case, given the multi-functional character of most projects.

Table 4. Summary of restoration types.

Type	Project area	Financing	Amount of funding	Key aspects	Environmental benefits	Socio-economic benefits
1	Large, mostly more than 100,000 ha	International donors with occasional support from national governments and/or investors	High, mostly higher than 10,000 k US$	1. Monitoring plan related to the objectives, baseline assessment included 2. Addressing the causes of degradation	1. Improvement of biodiversity 2. Providing ecosystems services (water and C sequestration)	1. Improvement of rural livelihoods 2. Capacity building of community
2	Intermediate, mostly between 500 and 5000 ha	Private funds, mainly impact investors but also private companies and owners of properties	Varying	Monitoring often neglected		1. Revenues from timber products 2. Capacity building of community
3	Small, mostly less than 500 ha	Public funds, mainly national governments and occasionally national and international donors	Low, mostly less than 500 k US$	Monitoring plan often included, baseline only occasionally	1. Improvement of biodiversity 2. Regulation of hydrological processes	1. Capacity building of community

Many projects claimed to have identified the drivers of degradation and actions to address them were proposed in their designs. However, most focused on the biophysical aspects of unsustainable land use only, whereas the socio-economic aspect remained underexposed in the majority of restoration projects. If the underlying causes like inequitable access to resources and political economy factors are to be understood, economic and institutional conditions must be studied (Pacheco and Poccard-Chapuis 2012). To tackle the underlying drivers, national governments should start developing intersectoral legal frameworks, including economic development, forestry and environmental policies, and remove perverse incentives that encourage degradation of forests and deforestation. These contextual factors need to be addressed as we move from large-scale restoration commitments to successful large-scale implementation.

This typology does not pretend to be complete. Although our database covered projects from twelve biomes across LAC using a wide range of restoration approaches, the level of detail captured in the database was a compromise between completeness of project data and the easiness of access to information sources. The typology could probably be further improved through the inclusion of additional variables. For example, variables related to economic and financial factors such as return on investment could serve as a useful indicator for financial gains, particularly for impact investors, but was only mentioned in a few project descriptions. Cost-benefit analyses are also needed to allocate the available financial resources efficiently and to facilitate prioritization (Rey Benayas *et al* 2009, Menz *et al* 2013) but the economic assessment of natural capital is still in its infancy (Bullock *et al* 2011).

Moreover, it is well known that uncertain or insecure land tenure negatively affect motivation and capacities to invest capital or labor to improve land, and thus are a major limitation to the sustainability of restoration projects (Lamb *et al* 2005, Duchelle *et al* 2014). Unfortunately, explicit information on land tenure issues was not provided in many projects. However, and in spite of the information limitations, our analysis outlines a general picture of how restoration projects are being implemented in LAC.

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