Biological Conservation 302 (2025) 110973

Contents lists available at ScienceDirect

Biological Conservation

journal homepage: www.elsevier.com/locate/biocon

Challenges for policy and practice in meeting ambitious ecological restoration targets by 2030: A perspective from Colombia

Mauricio Aguilar-Garavito [b,c,*], Paola Isaacs-Cubides [a,c], Natalia Peña-González [c,d], Eleanor Warren-Thomas [e,f]

[a] *Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Colombia*
[b] *Department of Biology, Sciences Faculty, Pontificia Javeriana University, Carrera 7 No 43-82 Edf. 53, Ofic. 408 B, 110231 Bogotá, Colombia*
[c] *Red Colombiana de Restauración Ecológica, REDCRE, Bogotá, Colombia*
[d] *Instituto de Investigaciones Marinas y Costeras "José Benito Vives de Andréis" (INVEMAR), Colombia*
[e] *School of Environmental and Natural Sciences, Bangor University, United Kingdom*
[f] *Biodiversity and Natural Resources Program, International Institute for Applied Systems Analysis (IIASA), Austria*

A R T I C L E I N F O

Keywords:
Environmental compensation
Biodiversity offsetting
Biodiversity offsets
Funding sources
Monitoring practices
Public policies
Standards of ecological restoration

A B S T R A C T

Targets for ecosystem restoration have been made at global, regional, and national scales, but monitoring of progress remains challenging. Differences in definitions, goals, and practices among restoration initiatives, linked to policy drivers and funding sources, add complexity. We evaluate the current state of ecological restoration activity in Colombia, where, since 2012, legal requirements to compensate for environmental damage may be driving widespread restoration efforts, alongside a long history of government and private restoration initiatives. We systematically searched several public databases, and circulated an online survey, to collect records of 675 terrestrial and coastal restoration projects initiated between 1963 and 2021, capturing data on: location, funding, monitoring, ecosystem type and actors. Location was reported for 613 projects at municipality level, and 261 projects at point level. Restoration aims included recovery of ecological processes, hydrological processes, soil erosion, and natural resources. Only 24 % reported any monitoring, with just 2 % monitoring effectiveness. Forty-one percent of projects were enacted under environmental compensation laws. Funding was mostly from within Colombia, with minimal international funding. This work highlights major gaps in the monitoring needed to achieve effective implementation of restoration targets. Enhancing coordination among institutions, and enhancing monitoring, will now be crucial to achieving restoration goals.

1. Introduction

Ecological restoration, including restoration of forest cover, seeks to achieve multiple benefits for nature, climate, and people (Chazdon and Brancalion, 2019). Ambitious restoration goals have been set at the global level, including the Bonn Challenge (IUCN, 2020), the New York Declaration on Forests (Forest Declaration Assessment, 2021), the Global Biodiversity Framework commitment to restore 30 % of degraded lands by 2030 (CBD, 2024b), and the United Nations Decade on Ecosystem Restoration (UN, 2024). In Latin America, restoration can be considered part of a new vision for socio-economic development, and is strongly driven by the international agenda (Meli et al., 2017), with ratification of global targets complemented by regional targets, such as Initiative 20 × 20 that currently aims to bring 50 million ha of degraded land under restoration by 2030 through country-led projects (WRI, 2024). Against this complex background of commitments, a key global challenge lies in defining when restoration has been achieved and tracking progress towards targets. Initiatives such as the Restoration Barometer (IUCN, 2024) allow countries and individuals to provide information about restoration projects in a central location, but rely on voluntary upload of information.

In Colombia, a megadiverse country supporting nearly 10 % of global biodiversity (CBD, 2024a), a national restoration strategy was adopted in 2012 with area-based targets set every four years (Meli et al., 2017).

* Corresponding author at: Department of Biology, Sciences Faculty, Pontificia Javeriana University, Carrera 7 No 43-82 Edf. 53, Ofic. 408 B, 110231 Bogotá, Colombia.

E-mail addresses: daguilar@javeriana.edu.co (M. Aguilar-Garavito), pisaacs@humboldt.org.co (P. Isaacs-Cubides), natalia.pena@invemar.org.co (N. Peña-González).

https://doi.org/10.1016/j.biocon.2025.110973
Received 12 September 2024; Received in revised form 28 November 2024; Accepted 6 January 2025
Available online 14 January 2025

Colombia has a long history of restoration activities and policies since pioneer projects in the 1950s (Murcia et al., 2016), and a National Restoration Plan now guides the location of restoration activities under multiple mechanisms (Ministerio de Ambiente y Desarrollo Sostenible, 2015). Restoration targets are also built into national policies on agricultural expansion, forest management, and climate change (FABLE, 2023). Ecological restoration in Colombia is also driven by legal requirements to compensate for biodiversity loss following transport infrastructure, hydrocarbon, mining and energy developments (Ministerio de Ambiente y Desarrollo Sostenible, 2012). In these cases, ecological restoration is used to offset biodiversity loss as part of the mitigation hierarchy within the environmental licensing process overseen by the National Environmental Licensing Authority (ANLA) (Murcia et al., 2017). Despite these political and social intentions, Colombia currently reports only 378,625 ha under restoration, with 152,622,941 trees planted (Ministerio de Ambiente y Desarrollo Sostenible, 2023). Moreover, no plans or policies at the national scale include a concrete mechanism to report compliance with targets, or to monitor outcomes of restoration activities.

Defining the successful outcome for an ecological restoration process in the context of differing restoration goals is challenging. Success has often been measured through the number of established trees or plants, the area over which restoration activity has taken place, and the assessment of vegetation cover (Aguilar-Garavito and Ramírez, 2015). These indicators, while useful, are deficient as proxies for the real process, leaving out many relevant ecosystem and socioeconomic processes (Chazdon and Brancalion, 2019). Understanding what measures are being used to define ecological restoration success in existing projects, and what this may mean for successful restoration outcomes, is therefore critical.

In this study, we collected comprehensive information on the location and status of ecological restoration projects implemented by public and private investment throughout Colombia, building on records collected via a questionnaire survey in 2012 (Murcia and Guariguata, 2014). We used data from multiple publications, official reports, existing databases, and direct communication with researchers and restoration professionals via an online survey. We posed the following key questions: 1) To what extent is ecological restoration driven by legal frameworks? 2) What proportion of restoration projects are funded by the private sector versus the public sector? 3) How are restoration projects spatially distributed in relation to different ecosystems and protected areas? 4) What type and extent of monitoring is being carried out?

2. Material and methods

Data on existing restoration projects in Colombia was collated from two publicly available databases in Colombia: SECOP (the national "Electronic Public Procurement System" that contains data on all contracts made using public funds, capturing restoration contracts held by public and private sector contractors, https://www.colombiacompra.gov.co/secop/secop), and ANLA (the "National Authority of Environmental Licenses" database of environmental compensation projects, https://datosabiertos-anla.hub.arcgis.com). The ANLA database captures ecological restoration actions conducted as part of environmental compensation requirements for large infrastructure projects (defined as those that cover the jurisdiction of multiple environmental authorities or overlap multiple National Parks or departments). A third government database, SNIF (the "National Forestry Information System", http://snif.ideam.gov.co/ideam-snif-web) records forestry projects enacted by regional authorities in Colombia, including those related to restoration, but this data was not accessible for the purposes of the study due to restrictions on data use.

Data was also collected via direct communication with stakeholders involved in restoration in Colombia, identified via the Colombian Ecological Restoration Network (REDCRE); letters of invitation and online meeting requests were sent to forty-seven people (Supplementary Table 1), inviting them to share information as part of the study. Multiple parties expressed interest but were not able to share full technical documents or reports. An online survey was therefore also designed to collect data from the same stakeholders, to collect specific information about restoration projects. This survey form was sent to the same stakeholders (survey structure shown in Supplementary Text 1). However, participation was very low, with only nine people completing the form.

Four existing databases of restoration projects were also included in the data collection: a database compiled by CIFOR in 2012 via a questionnaire survey (Murcia and Guariguata, 2014), the MANRESCO v. 1.0 database of mangrove restoration projects compiled by INVEMAR, the Colombian government research institute for coastal, marine and oceanic ecosystems (Rodríguez-Rodríguez et al., 2021), the REDCRE database (Peña-González et al., 2018) which included restoration projects presented at scientific events, and a database of ecological restoration projects focused on soils (Durán Dueñas, 2018).

All data was stored in an Excel database (Supplementary Data 1), capturing data on key aspects of project location, disturbance type, finance, ecosystem, aim of restoration, presence and duration of monitoring, and whether the project was part of an environmental compensation scheme (Table 1). Data was collected between September 2021 and March 2022.

Duplicate information across the different sources was removed by cross-checking and complementing and confirming information when necessary. Restoration projects were only included in the database if they contained information on location (to at least department level within Colombia), date of intervention, and the type of restoration. Projects that did not have restoration as their main objective, or only reported characterization of restoration needs without evidence of implementation, were excluded.

2.1. CIFOR database

Of the 119 restoration projects presented by Murcia and Guariguata (2014), ten projects were not included in our database due to lack of information and supporting documentation, and lack of certainty about implementation of restoration action where titles of reports included terms such as "diagnoses" or "guidelines".

2.2. ANLA database

The National Environmental Licensing Authority (ANLA) is responsible for ensuring that development subject to licensing complies with environmental regulations, including ecological restoration where required within the mitigation hierarchy. Private companies must present and execute restoration plans as part of offsets and report them to ANLA. Only projects with core information were incorporated into the database for this study (as a minimum, the number of hectares, date of initiation or publication, type of restoration action), and that had been approved, executed, or were currently being executed.

The ANLA database contained 2160 records of "1 % investment" projects from companies capturing surface and groundwater resources – a legal obligation as part of obtaining water rights. However, only 98 projects were approved and supervised by ANLA, and of these only 20 records related to restoration and had the core information required for inclusion in the database. The remaining records reported improvement activities in rural aqueducts, water treatment systems, environmental education programs and workshops. In addition, 2100 records of ecological restoration for offsetting were reported, of which 700 projects had been executed or were in execution, but only 176 records contained core information and were included in the database.

Table 1
Key data fields in the restoration project database.

Data field	Description
Numeric ID	Unique ID number for project
Title of the project	Project title
Author / Contact / Contractor	Key contact/contractor for project information
Organization	Organization conducting restoration project
Organization type	Environmental authorities/National Natural Park/University/Company/NGO/Botanic Garden/Research institute/Municipal authority/Ministry of the Environment/Individual
Type of financing	National government/National and International/National/ International
Type of executor	Private/Public/Public and private
Date of publication (Year)	Date reported in publication
Activity initiation (Year)	Date reported in publication
Compensations	Yes/No
Project phases	Diagnosis/Implementation/Planning
Monitoring	Yes/No
Years of monitoring	<1 year/1–5 years/>5 years
Target land cover	Mining extraction areas/Mosaic of crops with natural spaces/Urban green areas/Mosaic of crops, pastures and natural areas/Mosaic of pastures and crops/Mosaic of pastures and natural spaces/Wooded pastures/Weeded pastures/Lagoons, lakes and natural swamps/Shrubland/Grassland, Scrubland/Plantation Forest/Secondary or transitional vegetation/Grassland
Type of restoration approach	Assisted restoration/Natural regeneration/Assisted restoration and Natural regeneration
Restoration actions	31 different actions identified e.g. enrichment planting, vegetation nucleation, perches, live fences, invasive species control
Disturbance	Several disturbances/Mining and extractive industry/Civil works and infrastructure/Agricultural and livestock use/Urban sprawl/Invasive species/Forest plantations/Deforestation/Natural origin/Fires/Livestock use
Type of land being restored	Forestry/Forestry-production/Urban areas/Forestry protection-production/Forestry-protection/Agroforestry/Civil works and infrastructure/Mining and extractive industry
Main aim of restoration	Ecological connectivity/Soil erosion prevention/Recovery and conservation of natural resources/Hydrological restoration/Water resource protection/Production (agroforestry/silvo-pasture)/Control and elimination of invasive species/Ecological restoration of mangroves/Reef restoration/Disaster risk management
Area of land in project (Ha)	Area reported to be under restoration
Latitude	If point location available, in decimal degrees
Longitude	If point location available, in decimal degrees
Department-Municipality	Unique combination of department and municipality name, used in mapping
Location	Name of location e.g., national park, village
Biogeographic province	Following (Hernández et al., 1991)
Potential Ecosystem	Potential ecosystem based on project location, following (IDEAM, 2017)
Reference	URL for original reference document, if available
Source	If sourced from ANLA/SECOP/MANRESCO v. 1.0 databases
Costs	Any reported costs in USD

2.3. SECOP database

The electronic system of public procurement was searched using keywords: *restoration, recovery, rehabilitation, planting,* and *sowing*. This resulted in >1000 records of contracts related to ecological restoration. Several records were discarded that were related to machinery contracts, maintenance, purchase of inputs or tools, calls for bids or tenders, or contracts that were published but were not executed or were not completed. Only contracts that had been completed or concluded were included. Where necessary, contracts were reviewed completely to extract information on the number of hectares and type of restoration, given that in many cases the project titles did not provide much information.

2.4. Classification of restoration approach

Projects were classified into three main categories based on the type of intervention used during the ecological restoration process, following principles established by the Society for Ecological Restoration (Gann et al., 2019), Chazdon et al. (2016), Holl and Aide (2011), and Aguilar-Garavito and Ramírez (2021).

Assisted restoration: this approach involves specific human interventions aimed at facilitating or accelerating natural restoration processes, particularly in areas where ecosystem conditions do not allow spontaneous recovery within reasonable periods. These interventions include activities such as planting native species, controlling invasive species, and improving soil conditions (Society for Ecological Restoration International, 2004; Holl and Aide, 2011).

Natural regeneration: this category corresponds to spontaneous recovery processes that occur when the disturbances or pressure limiting regeneration are removed. This approach relies on the inherent capacity of ecosystems to self-recover, allowing biodiversity and functionality to be restored without direct human intervention (Chazdon et al., 2016; Society for Ecological Restoration International, 2004).

Assisted restoration and natural regeneration: this category combines elements of assisted restoration and natural regeneration. Initial human interventions, such as soil stabilization or the introduction of key species, are used to promote long-term natural recovery processes in partially degraded areas (Gann et al., 2019; Aguilar-Garavito and Ramírez, 2021).

Each project was classified into one of these categories based on descriptions available in project records and serve as the conceptual framework for analyzing restoration actions in Colombia in this study.

2.5. Location data

Where possible, point location data was obtained for project records based on the description of the project location. Specifically, out of the 675 projects analyzed, 613 provided detailed information beyond the name of the municipality and department, such as coordinates or specific site descriptions. Among these, 261 projects included precise point coordinates, which were validated for accuracy before use.

3. Results

A total of 675 ecological restoration projects met the criteria for inclusion in the database, with project dates ranging from 1993 to 2021 (Fig. 1, plus a single project in 1963 not shown). The year with the highest number of projects reported was 2013 (60 projects). Four hundred and thirty projects (64 %) provided explicit data on the area of land under restoration, while the remaining 245 projects (36 %) provided no data on the area under restoration. The total sum of the area covered by the 430 projects that did provide area data was 111,593 ha.

3.1. Actors

The number of projects enacted as part of environmental compensation schemes has remained relatively steady since 2005, totaling 188 (29 % of records), with the majority being enacted by companies, and a few by NGOs, universities, or National Natural Parks (Supplementary Fig. 1). Companies were the most common restoration actors overall, running 211 projects (31 %), followed by environmental local corporations (144 projects, 21 %) and NGOs (88 projects, 13 %). This pattern may be driven by accessibility of data from the ANLA and SECOP databases, whereas it is more difficult to gather data on projects developed by private actors. Other actors include the Ministry of Environment (57 projects, 8 %), universities (32 projects, 5 %), municipal authorities (28

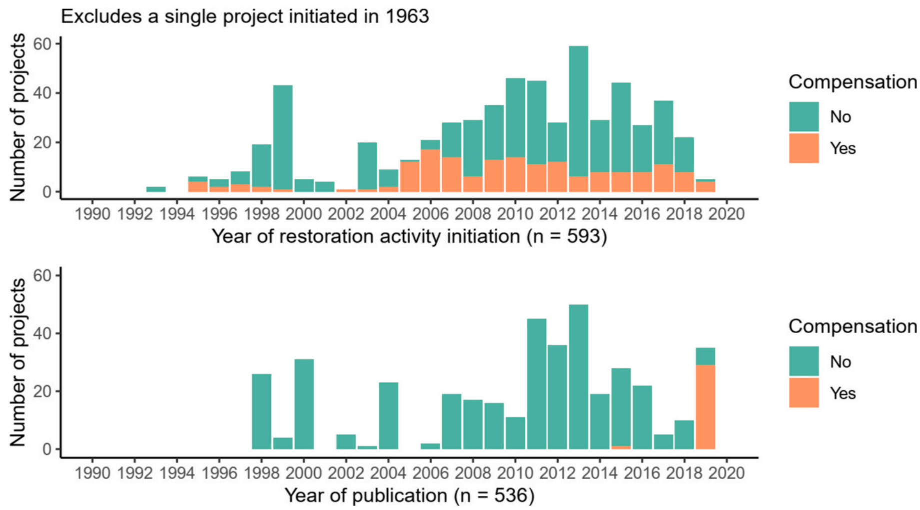

Fig. 1. Number of projects recorded by year according to the year of initiation (top) and publication (bottom).

projects, 4 %), research institutes (27 projects, 4 %), and National Parks and the Botanical Garden of Bogotá (22 projects, 3 %, each). In total, 53 % of the projects were carried out by public entities, 37 % by companies, while NGOs and academia only contributed 5 % of the projects respectively.

3.2. Restoration actions

Assisted restoration was the most common restoration approach (448 projects, 66 %), mostly in compensation projects enacted by companies, followed by the combination of assisted restoration and natural regeneration (120 projects, 18 %) and natural regeneration (80 projects, 12 %; Supplementary Fig. 2).

A combination of several restoration techniques was evidenced in most of the projects. The most common techniques were tree planting (243 projects, 36 %), perimeter fencing and area conservation (68 projects, 10 %) and aquatic restoration (54 projects, 8 %, Supplementary Fig. 3).

3.3. Location and ecosystem types

The greatest concentration of projects was found in the Norandina region (328 projects, 49 %), which is the most degraded and densely populated area of the country, containing highly degraded ecosystems such as the high Andean, Andean and sub-Andean forests, and paramo ecosystems (Fig. 2). These projects are in the departments of Cundinamarca (85 projects, 13 %), Antioquia (80 projects, 12 %), and Casanare (68 projects, 10 %).

The Orinoquia region also had many projects (104 projects, 15 %); this region is characterized by the presence of extractive industries,

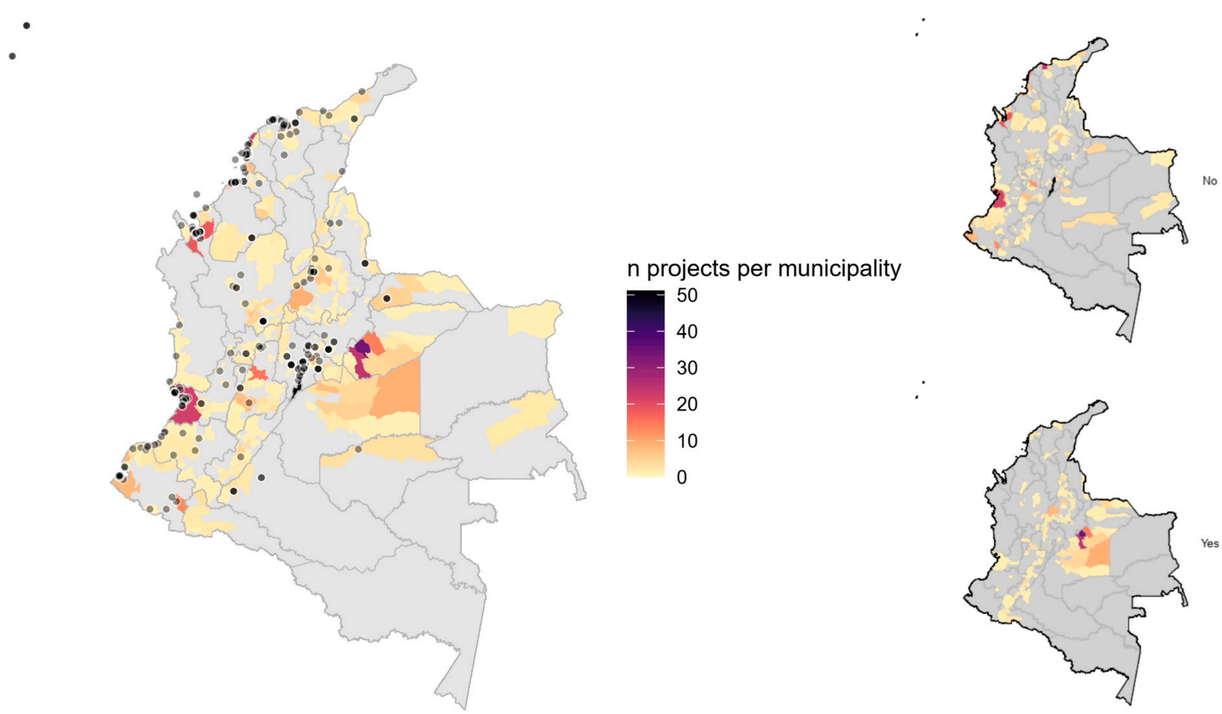

Fig. 2. Total number of ecological restoration projects per municipality, with point locations where available, for all projects (main map), restoration projects implemented voluntarily (top right inset, compensation = "no"), or as part of environmental compensation schemes (bottom right inset, compensation = "yes"). projects.

mostly oil, and many environmental offset processes have been carried out. Data on most projects in this region were extracted from the ANLA database, where ecosystem type was not reported. The most predominant ecosystems in this region are savannas, but riparian forests, morichal forests, wetlands, and lagoons also exist.

Mangrove ecosystems had the greatest number of projects (166 projects, 25 %, Supplementary Fig. 4), which are found in the Caribbean and Choco-Magdalena regions and are partly well-represented in the data due to targeted projects and a specific database focused on this ecosystem (MANRESCO). However, other ecosystems that provide direct benefits for people, such as the paramo (20 projects, 3 %) and wetlands (12 projects, 2 %), and ecosystems at risk of loss, such as the tropical dry forest (28 projects, 4 %), had few reported restoration projects. Finally, only 11 projects (2 %) were identified in the Amazon region.

3.4. Type of land disturbance and restoration aim

The main land disturbances reported by restoration projects are areas affected by civil works and infrastructure (162 projects, 24 %, Supplementary Fig. 5), mining and extractive industries (153 projects, 23 %), deforestation (62 projects, 9.2 %), agriculture and livestock (53 projects, 8 %) and areas affected by invasive plants (41 projects, 6 %). In addition, 45 projects (7 %) reported several types of disturbance, while 162 projects (24 %) did not provide any information on the type of disturbance.

The aims of restoration differed among projects, and while all mangrove projects were enacted with the aim of ecological restoration, multiple aims were reported for other ecosystems (Fig. 3). The recovery and conservation of natural resources (233 projects, 35 %, Fig. 3), was most common, followed by the protection of water bodies (119, 18 %) and the ecological restoration of mangroves (103 projects, 15 %). By far the largest project in terms of area aims to improve ecological connectivity in a flooded savannah.

3.5. Monitoring

Projects should include a monitoring process with criteria and indicators to demonstrate changes in structure, composition, function, and socioeconomic aspects, to establish compliance with restoration objectives and show changes over time. Only 6 % of projects (12 projects) conducted as part of environmental compensation schemes reported any type of monitoring, leaving 176 projects with no apparent monitoring (Supplementary Fig. 6). In contrast, 31 % (141 projects) of non-compensation projects reported some level of monitoring. Across all projects, 67 (10 %) reported monitoring lasting less than one year, 70 reported monitoring of 1–5 years (11 %), and only 15 projects (2 %) reported monitoring for more than five years.

In most cases, projects with monitoring (lasting from less than one year to five years) focused exclusively on evaluating the implementation of proposed restoration actions. This means they primarily verified whether the planned activities were conducted and whether the proposed targets were met, particularly in terms of the number of hectares implemented and the location of intervention sites. Some projects that conducted short-term (more than one year) and medium-term (one to five years) monitoring additionally evaluated the survival and growth of planted vegetation.

On the other hand, the few projects that performed long-term monitoring (over five years) included some indicators to assess ecological processes, such as succession, and landscape metrics, such as connectivity and patch size. However, these projects are rare and are either associated with large-scale initiatives with significant funding, or are academic studies conducted by universities.

Beyond the data on monitoring duration, it was not possible to obtain detailed information about the specific types of monitoring conducted in most projects. For example, the use of techniques such as remote sensing, in-person monitoring, or biodiversity tracking with camera traps was not explicitly reported. This represents a significant gap, as such data could provide valuable insights into the quality and focus of restoration efforts. Emerging markets, such as premium carbon credits and biodiversity credits, increasingly demand evidence of restoration effectiveness, which may influence the design of future monitoring efforts. This highlights the need for standardized reporting protocols to capture the type and quality of monitoring in restoration projects, which could significantly improve the transparency and effectiveness of restoration practices in Colombia.

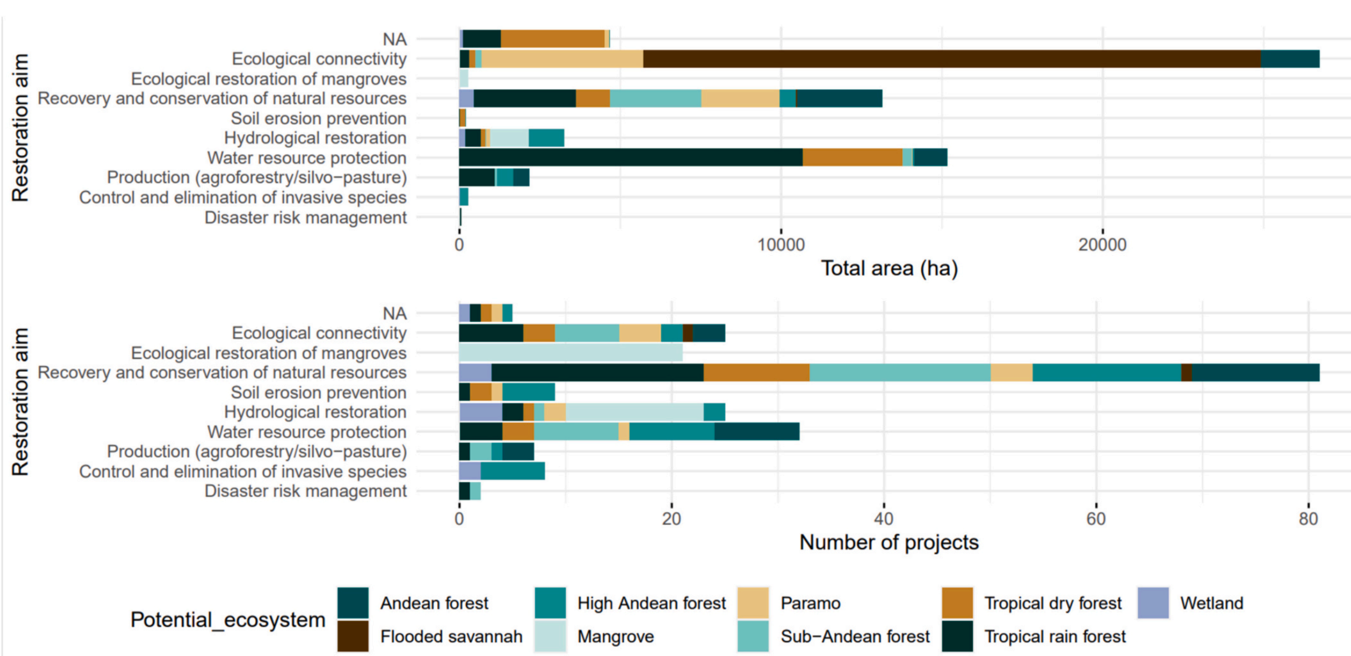

Fig. 3. Number of projects and their area according to the restoration aim and the type of ecosystem.

3.6. Funding sources

Funding for restoration mostly came from national sources (599 projects, 89 %), followed by mixed contributions from both national and international sources (18 projects, 3 %). Most projects were supported by public funding, followed by private funding, most of which were supported by companies and represented environmental compensation schemes (Fig. 4). Projects run by other organizations, such as universities, research institutes, NGOs, National Parks, companies and regional authorities, were predominantly funded by public funds.

4. Discussion

In this study, we collected comprehensive information on the location and status of ecological restoration projects implemented by public and private investment throughout Colombia. First, we determined to what extent ecological restoration is driven by legal compensation frameworks, thus generating zero net restoration, instead of net ecosystem gain. Additionally, we analyzed the proportion of projects funded by the private sector versus the public sector and examined the spatial distribution of projects in relation to different ecosystems and protected areas. Finally, we evaluated the type and scope of monitoring being carried out. These analyses provide a deeper understanding of the challenges and opportunities for ecological restoration in Colombia, highlighting the need to improve the effectiveness and impact of these initiatives. They also offer perspectives for developing ecological restoration in Latin America and the Caribbean, as well as in other developing countries.

Different national policies in Colombia have coincided with peaks in the initiation of restoration projects. The Strategic Plan for the Restoration and Establishment of Forests in Colombia (Ministerio del Medio Ambiente, 1998) coincided with the year in which publications about restoration projects started, while a second surge in project activity can be identified after the publication of the National Restoration Plan (Ministerio de Ambiente y Desarrollo Sostenible, 2015). The "National Strategy for Environmental Compensation" (Ministerio de Ambiente y Desarrollo Sostenible, 2012) provides tools to guide compensation actions to offset environmental impacts, focusing on preservation, restoration, and sustainable use, in line with biodiversity management policies. This instrument improved the implementation and compliance of restoration projects linked to extractive activities, and generated progress in both restoration investment and monitoring that would otherwise be difficult to achieve, but did not coincide with an increase in restoration project implementation. In the case of non-offset projects, there was an increase in 2013 (the year with the greatest number of projects over the study period), followed by further increases in 2015 and 2017. This may have been driven by incentives through Initiative 20 × 20 (WRI, 2024), the National Biodiversity Action Plan (NBSAP; Ministerio de Ambiente y Desarrollo Sostenible, 2017), and governmental targets.

There were also many projects published in 2021. This may be related to the government's commitment to plant 180 million trees by 2022, following the 'Champions for One Trillion Trees' initiative formed at the Davos meeting in 2019, which stimulated entities such as ANLA, the Ministry of Environment and the District Secretary of the Environment of Bogotá to update their project databases. This initiative also indicated the planting of two trees for each employee of private companies, to promote reforestation. A legal instrument, law 2173 of 2021, was initiated, but this was postponed while a better planning process for restoration was developed (Gobierno Nacional, 2021).

While public policies and national or international commitments have led to an increase in the number restoration projects, particularly in the years following their definition or ratification (as detailed below), growing academic and social interest in restoration has also played a significant role in driving the development of restoration activities (Aguilar-Garavito and Ramírez, 2016). The creation of ecological restoration research groups (Supplementary Table 3) has promoted various research and thesis projects. Since 2009, the organization of five restoration congresses and other scientific events has facilitated the exchange of interdisciplinary practices and the establishment of the Colombian Network for Ecological Restoration (REDCRE) in 2013. This network has fostered collaboration and teamwork among individuals and entities interested in restoring Colombia's ecosystems (Aguilar-Garavito et al., 2017; Aguilar-Garavito and Ramírez, 2018).

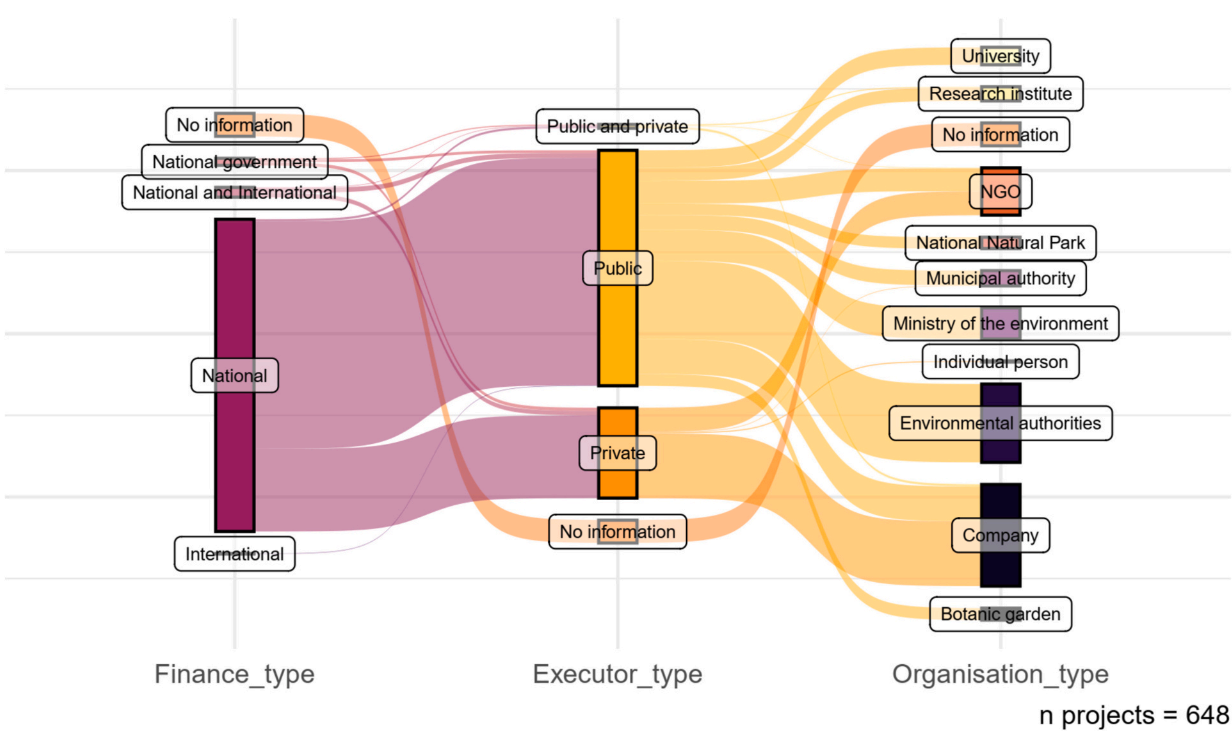

Fig. 4. Finance type, executor type and organizations implementing restoration projects in Colombia.

In Colombia, ecological restoration continues to be funded with public money allocated from development plans, and with resources provided by private companies within the framework of environmental compensation for biodiversity loss. These funding modalities are consistent with the historical framework that the country has had for ecological restoration processes (Murcia et al., 2016) and are also defined by Government Plans (Presidencia de la República, 2010, 2014, 2018, 2022), the National Restoration Plan (Ministerio de Ambiente y Desarrollo Sostenible, 2015), and the National Compensation Strategy (Ministerio de Ambiente y Desarrollo Sostenible, 2012). However, international funding, or funding from national institutions that are not legally obligated to restore, remains limited and sometimes disjointed. There is also no clear funding from civil society or other types of donors. According to (Murcia and Guariguata, 2014), this makes sense because government has been the major driver of restoration in Colombia, through the generation of guidance documents, policy and funding.

Despite this trend, we can highlight a significant change in the state of ecological restoration in Colombia since 2014. Murcia and Guariguata (2014) and Murcia et al. (2017) found that ecological restoration was primarily led by the government in 63 % of the projects, while the private sector contributed only 5 %. However, our study shows the private sector contributes 37 % of the projects, while the state contributes 53 %. This is directly obligation by companies to compensate for environmental damage since 2012 (Ministerio de Ambiente y Desarrollo Sostenible, 2018). Therefore, the state has partly delegated its restoration responsibility to companies that are being granted environmental licenses for road, infrastructure, and extractive industry projects. Accordingly, it is possible that ecological restoration in Colombia is being used not to restore historically degraded areas but to address new areas being degraded by current economic development policies (Aguilar-Garavito et al., 2015).

The spatial distribution of restoration projects continues to follow historical trends (Murcia et al., 2016), as well as the distribution reported by the Ministry of Environment (Ministerio de Ambiente y Desarrollo Sostenible, 2023), being mainly concentrated in the Andean region and departments such as Cundinamarca, Antioquia, and Casanare, which have high densities of both population and extractive industry projects. This is related to the centralized development of the country, and because the main universities, NGOs, and companies have their headquarters in these regions (Aguilar-Garavito and Ramírez, 2015). On the other hand, there is a strong increase in mangrove restoration in coastal regions, thanks to the leadership of INVEMAR in implementationco, as well as the registration and reporting of projects (Rodríguez-Rodríguez et al., 2021; Rodríguez-Rodríguez, 2022). We found many issues with the accuracy of reporting project location, as coordinates provided in documents in most cases did not correspond to the location of restoration implementation, further confirming the need for a standardized and centralized registry.

In Colombia there are no standards or open repositories for documenting restoration projects, so entities that are not obligated or interested in reporting their restoration activities do not do so, making it difficult to identify many restoration activities (Aguilar-Garavito and Ramírez, 2016; Murcia et al., 2017). To date, only 10 % of the “1 % investment” water rights projects can be monitored and corresponds with offset projects (IDEAM, 2024). Further, although the National Forest Information System (SNIF) exists, it was not possible to access the data at the time of the review as the database was being updated, and in any case, this system only captures forest planting and not other ecosystems.

There is a notable gap in restoration of tropical dry forests, wetlands, coral reefs, seagrass, and páramos. Despite their significant importance in terms of social benefits and their threatened status, these ecosystems have few projects. This may be due to the lack of biophysical and social information available, the small number of companies, experts, NGOs, and academic institutions near these areas, their intrinsic biophysical and social difficulties, and issues related to land tenure and productive intensity, which make it difficult to find available land for developing ecological restoration processes (Aguilar-Garavito et al., 2015; Aguilar-Garavito and Ramírez, 2016), as well as the high costs associated with research and the implementation of restoration strategies in marine-coastal ecosystems.

The limited restoration efforts in coastal-marine environments, such as coral reefs, seagrasses, and mangroves, highlight the need for innovative funding mechanisms to address these critical ecosystems. Although our study did not specifically focus on identifying restoration opportunities related to carbon markets, the financing potential of these mechanisms is undeniable. In this regard, blue carbon ecosystems (mangroves, seagrasses, and salt marshes), due to their ability to sequester and store carbon up to ten times more efficiently than terrestrial forests, could significantly benefit from these initiatives. In this context, the Colombian Caribbean, with its extensive seagrass meadows, stands out as one of the largest carbon reservoirs in seagrass soils per unit area globally (Serrano et al., 2021).

Projects aligned with “blue carbon” initiatives could attract private sector investment, creating a sustainable funding model for marine-coastal restoration. By leveraging this mechanism, Colombia could address restoration gaps in coastal areas while simultaneously strengthening its role in the carbon market and contributing to global climate goals (see Palacios et al., 2021).

The work of Murcia and Guariguata (2014) identified that only 63 % of 119 projects assessed had a monitoring plan and 46 % had an implementation compliance evaluation plan. In this study, we find that the deficiency in monitoring persists as 77 % of the projects do not have monitoring. Ten percent of the projects only conducted implementation monitoring, meaning verification of works and development of plant material or mortality during the first 10 or 12 months of the process, and only 2 % conducted effective monitoring. Additionally, the monitoring is based solely on the development and coverage of planted vegetation, neglecting indicators with socioeconomic or biophysical relevance such as water quality or fauna associated with the restoration process.

Although Colombia has set a goal for the number of hectares restored, official reports on show 100 projects and 378,625 ha under restoration (Ministerio de Ambiente y Desarrollo Sostenible, 2023). However, we found more projects (675) but a smaller restored area (111,539 ha).

According to the above, it is necessary to have a public, open, and standardized platform to report and analyze restoration projects. Exercises like the RESTOR platform (Crowther Lab/ETH, 2024) and the IUCN Restoration Barometer (IUCN, 2024), allow the registration of projects and browsing of information about carbon, biodiversity, climate and related in one place. However, there should be mandatory standards for everyone involved in ecological restoration processes in Colombia to report their activities. In other places, such as Australia, such standards have been developed with very satisfactory results (SERA, 2018; Nelson et al., 2024). These standards can be adapted to Colombia by considering national documents such as the National Restoration Plan and the publications on restoration monitoring from the Instituto Humboldt (Aguilar-Garavito and Ramírez, 2015; Aguilar-Garavito and Ramírez, 2021). Additionally, they should focus on developing ecological restoration based on their mission while being supported by other institutions within the National Environmental System and academia.

The country has shown a growing commitment by implementing an increasing number of hectares under restoration. However, efforts to ensure the sustainability of these processes over time have been insufficient. This is concerning, as ecosystems are dynamic and highly sensitive to environmental, climatic, and social variables, which can interrupt or slow recovery trajectories. A clear example of this situation is the Ciénaga Grande de Santa Marta, which has been the subject of several restoration projects, such as PROCIÉNAGA and Manglares de Colombia. Due to its high environmental sensitivity, this ecosystem has been affected by processes like increased salinity caused by the El Niño phenomenon in 2017, resulting in significant losses of mangrove cover (INVEMAR, 2018). In 2021, a restoration project was implemented there as part of the 180 million Trees initiative, initially achieving an increase in mangrove cover. However, the lack of monitoring, maintenance, and adaptive management allowed the area to become clogged again with macrophytes and sediments, requiring a new intervention in 2023, funded with additional resources.

Examples of projects that have integrated monitoring include El Quimbo (Torres Romero et al., 2016; Moncada et al., 2020; Torres Romero, 2020), developed by Fundación Natura, with implementation and short-term effectiveness monitoring that confirmed achievement of restoration goals. Los Nevados (Peña-González, 2016; Instituto Alexander von Humboldt, 2017), led by Parques Nacionales Naturales, included similar monitoring but did not meet its objectives. El Neusa (Basto et al., 2018), implemented by Universidad Javeriana, demonstrated successful restoration outcomes, while Rabanal (Aguilar-Garavito et al., 2021), monitored by Instituto Humboldt, also reported goal achievement through robust monitoring. However, many projects provide insufficient detail in their reports, limiting the ability to assess the true scope of their monitoring efforts. Although all these projects mention conducting monitoring, most provide very few details in their reports, making it difficult to assess the depth and scope of their monitoring practices.

The combination of historical efforts, the development of a robust legal framework, and international commitments have solidified ecological restoration as a priority on Colombia's environmental agenda. However, significant challenges remain, including the need for sustainable funding, improving technical capacities, and effective coordination among various entities and actors involved in restoration processes. Furthermore, as (Aguilar-Garavito and Ramírez, 2015) conclude, the post-conflict opportunity in Colombia can be leveraged to further integrate ecological restoration, ensuring community participation, strengthening the institutional framework, and securing sustainable funding.

Given the dynamic and sensitive nature of ecosystems, it is essential to include short, medium, and long-term monitoring costs in restoration planning, as well as maintenance and adaptive management of restored areas, right from the initial planning and budgeting phases. This approach anticipates challenges and allows strategies to be adjusted based on seasonal, climatic, social, and even anthropogenic variations. Furthermore, monitoring provides an opportunity to train and develop local experts, who can replicate the acquired knowledge, thus ensuring the success and sustainability of restoration processes. Monitoring also plays a fundamental role in the adaptive management of restoration processes. It allows for timely detection of failures or difficulties, optimizing actions and ensuring continuous improvement. Additionally, it helps evaluate the cost-effectiveness of implemented strategies, facilitating better planning and execution of future processes. Without monitoring, it is impossible to determine the actual cost of restoration processes, their level of success, or to advance the field of ecological restoration.

Finally, we need to address constraints to the continuity of the ecological restoration projects in Colombia: 1) availability of high-quality planting material to achieve restoration goals, 2) legal tenure of land, 3) continuity of project management, 4) funding for monitoring, and 5) local capacity for project implementation.

5. Conclusions

This study identified historical and geographical trends in the implementation of ecological restoration in Colombia, along with common restoration types and funding sources. Despite progress, weaknesses were found, such as broad projects lacking adequate documentation and imprecise start dates, limiting the ability to assess project outcomes. Furthermore, the promotion of planting as the primary restoration technique, driven by national and international goals, often overlooks the specific ecological and social needs of each territory.

To improve the effectiveness of restoration projects, it is essential to establish an open, mandatory platform for reporting and monitoring efforts, along with standardized guidelines for restoration practices. Additionally, it is critical to evaluate contracting methods to ensure they address the short, medium, and long-term phases required for successful restoration. Well-documented and monitored projects should be prioritized for deeper studies, and participatory field validations or surveys should be conducted. Additionally, national mechanisms for submitting restoration reports should be improved, following existing manuals and protocols. These actions will lead to more accurate records, better project monitoring, and long-term sustainability through local participation and capacity-building.

In summary, while ambitious restoration goals can increase opportunities for funding and conservation, it is essential to prevent them from becoming perverse incentives that limit processes to simple techniques like planting, without considering the necessary diagnostics, monitoring, and maintenance to ensure restoration success.

CRediT authorship contribution statement

Mauricio Aguilar-Garavito: Writing – review & editing, Writing – original draft, Validation, Supervision, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Paola Isaacs-Cubides:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization. **Natalia Peña-González:** Writing – review & editing, Validation, Software, Methodology, Investigation, Data curation. **Eleanor Warren-Thomas:** Writing – review & editing, Writing – original draft, Visualization, Validation, Supervision, Software, Resources, Project administration, Methodology, Investigation, Funding acquisition, Formal analysis, Data curation.

Funding sources

Eleanor Warren-Thomas was supported by a Natural Environment Research Council NERC-IIASA Collaborative Fellowship NE/T009306/1.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Acknowledgments

We strongly thank Carolina Murcia (CIFOR), Juan Carlos Duran (National University), Yesenia Vásquez y Omar Velandia (ANLA), Jesica Rubio (REDCRE) and Alexandra Rodríguez (INVEMAR) for the data that they provided for this study, and all the entities that responded to our online survey.

Appendix A. Supplementary data

Supplementary data associated with this article can be found in the online version, at doi: https://doi.org/10.1016/j.biocon.2025.110973. These data include the Google map of the most important areas described in this article.

Data availability

Documents/reports collated as part of the data collection process are available from the lead author on request.

References

Aguilar-Garavito, M., Ramírez, W., 2015. Monitoreo a procesos de restauración ecológica aplicados a ecosistemas terrestres. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá D.C., Colombia.

Aguilar-Garavito, M., Ramírez, W., 2016. Fundamentos y consideraciones generales sobre restauración ecológica para Colombia. Biodiversidad En La Práctica 1 (1), 147–176. http://hdl.handle.net/20.500.11761/9894.

Aguilar-Garavito, M., Ramírez, W., 2018. Ecological restoration based on the Colombian legal system. In: Ceccon, En E., Pérez, D. (Eds.), Beyond restoration ecology: social perspectives in Latin America and the Caribbean, Sociedad Iberoamericana y del Caribe de Restauración Ecológica (SIACRE), pp. 155–176.

Aguilar-Garavito, M., Ramírez, W., 2021. Evaluación y seguimiento de la restauración ecológica en el páramo andino. Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá.

Aguilar-Garavito, M., Sierra, J., Ramirez, W., Vargas, O., Calle, Z., Vargas, W., Murcia, C., Aronson, J., Barrera Cataño, J.I., 2015. Toward a post-conflict Colombia: restoring to the future. Restor. Ecol. 23 (1), 4–6. https://doi.org/10.1111/rec.12172.

Aguilar-Garavito, M., Schlesinger, S., Ramírez, W., Hernández, A. M., & Franco-Morales, A. (2017). La restauración ecológica: Una mirada política y normativa. En L. A. Moreno, G. I. Andrade, & L. F. Ruíz-Contreras (Eds.), Biodiversidad 2016. Estado y tendencias de la biodiversidad continental de Colombia (pp. 45–46). Instituto de Investigación de Recursos Biológicos Alexander von Humboldt. 10.21068/B001.2016.405.

Aguilar-Garavito, M., Sesquille Escobar, E., Ruiz-Santacruz, J.S., 2021. Monitoreo de experiencias de restauración ecológica en páramos afectados por plantaciones forestales de *Pinus patula*: Un estudio de caso en el páramo de Rabanal. Biodiversidad en la Práctica, Boyacá-Colombia.

Basto, S.I., Moreno, A.C., Barrera, J.I., 2018. Restauración ecológica en áreas post-tala de especies exóticas en el parque forestal embalse del Neusa. Pontificia Universidad Javeriana. http://hdl.handle.net/10554/44696.

CBD, 2024a. Colombia - Country Profile. Secretariat of the Convention on Biological Diversity. https://www.cbd.int/countries/profile?country=co.

CBD, 2024b. Convention on Biological Diversity Kunming-Montreal Global Biodiversity Framework (GBF) 2030 targets (with guidance notes). https://www.cbd.int/gbf/targets (Accessed: 2 April 2024).

Chazdon, R., Brancalion, P., 2019. Restoring forests as a means to many ends. Science 365 (6448), 24–25. https://doi.org/10.1126/science.aax9539.

Chazdon, R.L., Broadbent, E.N., Rozendaal, D.M.A., Bongers, F., Zambrano, A.M.A., Aide, T.M., Balvanera, P., Becknell, J.M., Boukili, V., Brancalion, P.H.S., Craven, D., Almeida-Cortez, J.S., Cabral, G.A.L., de Jong, B.H.J., Denslow, J.S., Dent, D.H., DeWalt, S.J., Dupuy, J.M., Eastman, J.R., Poorter, L., 2016. Carbon sequestration potential of second-growth forest regeneration in the Latin American tropics. Sci. Adv. 2 (5), e1501639. https://doi.org/10.1126/sciadv.1501639.

Crowther Lab/ETH, 2024. RESTOR. https://restor.eco/es/about/.

Durán Dueñas, J. (2018). Análisis ambiental del suelo en proyectos de restauración ecológica de ecosistemas terrestres en Colombia (2003-2016). Universidad Nacional de Colombia. https://repositorio.unal.edu.co/handle/unal/68827.

Forest Declaration Assessment. (2021). What is the New York Declaration on Forests? https://forestdeclaration.org/about/new-york-declaration-on-forests/ (Accessed: 2 April 2024).

FABLE, 2023. Ecological restoration and deforestation control: Implications for Colombia's agriculture and climate goals. FABLE Policy Brief. Sustainable Development Solutions Network (SDSN) and International Institute for Applied Systems Analysis (IIASA), Paris/Laxenburg. Retrieved from https://www.foodandlandusecoalition.org/wp-content/uploads/2023/06/FABLE-Colombia-Brief_EN.pdf.

Gann, G.D., McDonald, T., Walder, B., Aronson, J., Nelson, C.R., Jonson, J., Hallett, J.G., Eisenberg, C., Guariguata, M.R., Liu, J., Hua, F., Echeverria, C., Gonzales, E.K., Shaw, N., Decleer, K., Dixon, K.W., 2019. International principles and standards for the practice of ecological restoration (2nd ed.). Restor. Ecol. 27 (S1), S1–S46. https://doi.org/10.1111/rec.13035.

Gobierno Nacional. (2021). Ley 2173 de 2021. Por medio de la cual se promueve la restauración ecológica a través de la siembra de árboles y creación de bosques en el territorio nacional.

Hernández, J., Hurtado Guerra, A., Ortiz Quijano, R., Walschburge Hernández, T., 1991. Unidades biogeográficas de Colombia. En Estado de la biodiversidad en Colombia: Informe final. Instituto Colombiano para el Desarrollo de la Ciencia y la Tecnología 'Francisco José de Caldas' –COLCIENCIAS.

Holl, K.D., Aide, T.M., 2011. When and where to actively restore ecosystems? For. Ecol. Manag. 261 (10), 1558–1563. https://doi.org/10.1016/j.foreco.2010.07.004.

IDEAM, 2017. Mapa de ecosistemas continentales, costeros y marinos de Colombia. Versión 2.1. http://www.siac.gov.co/ecosistemas.

IDEAM, 2024. Protocolo de monitoreo de la restauración de bosques mediante el uso de sensores remotos aplicable a otras coberturas forestales. Nivel Nacional. Versión 1.0.

Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, 2017. Monitoreo a procesos de restauración ecológica en áreas con cercado perimetral en el PNN Los Nevados. http://i2d.humboldt.org.co/ceiba/resource.do?r=rest_pnnnevados_2017.

INVEMAR, 2018. Monitoreo de las condiciones ambientales y los cambios estructurales y funcionales de las comunidades vegetales y de los recursos pesqueros durante la rehabilitación de la Ciénaga Grande de Santa Marta: Informe técnico final 2018, Vol. 17. INVEMAR, Santa Marta, p. 178. Retrieved from https://mail.corpamag.gov.co/archivos/Publicaciones/MonitoreoCondicionesAmbientalesCambiosINVEMAR.pdf.

IUCN. (2020). The Bonn Challenge. https://www.bonnchallenge.org/ (Accessed: 2 April 2024).

IUCN. (2024). Restoration Barometer. https://restorationbarometer.org/ (Accessed: 16 July 2024).

Meli, P., Herrera, F.F., Melo, F., Pinto, S., Aguirre, N., Musálem, K., Minaverry, C., Ramírez, W., Brancalion, P.H.S., 2017. Four approaches to guide ecological restoration in Latin America. Restor. Ecol. 25 (2), 156–163. https://doi.org/10.1111/rec.12473.

Ministerio de Ambiente y Desarrollo Sostenible, 2012. Manual para la asignación de compensaciones por pérdida de biodiversidad. Bogotá, Colombia.

Ministerio de Ambiente y Desarrollo Sostenible, 2015. Plan Nacional de Restauración. Restauración ecológica, rehabilitación y recuperación de áreas disturbadas. Ministerio de Ambiente y Desarrollo Sostenible, Bogotá, D.C., Colombia. https://archivo.minambiente.gov.co/index.php/bosques-biodiversidad-y-servicios-ecosistematicos/gestion-en-biodiversidad/restauracion-ecologica.

Ministerio de Ambiente y Desarrollo Sostenible, 2017. Plan de acción de biodiversidad para la implementación de la Política Nacional para la Gestión Integral de la Biodiversidad y sus Servicios Ecosistémicos 2016–2030. https://archivo.minambiente.gov.co/index.php/bosques-biodiversidad-y-servicios-ecosistematicos/politica-nacional-de-biodiversidad/plan-de-accion.

Ministerio de Ambiente y Desarrollo Sostenible, 2018. La restauración como acción de compensación para proyectos licenciables. https://www.minambiente.gov.co/wp-content/uploads/2021/10/Guia-La-Restauracion-como-accion-de-compensacion-para-proyectos-licenciables.pdf.

Ministerio de Ambiente y Desarrollo Sostenible, 2023. Estrategia Nacional de Restauración 2023–2026, Juntos para recuperar la naturaleza perdida. https://es.scribd.com/document/701102791/Estrategia-Nacional-de-Restauracion.

Ministerio del Medio Ambiente, 1998. Plan Estratégico para la restauración ecológica y el establecimiento de bosques en Colombia. Plan Verde.

Moncada, D.M., Borda, A.C., Vieira-Muñoz, M.I., Alcázar, C., González, M.R. (Eds.), 2020. Elevando la acción colectiva empresarial para la gestión integral del bosque seco tropical en Colombia. Minambiente, ANDI, ANLA, Instituto Humboldt, TNC, Bogotá.

Murcia, C., Guariguata, M.R., 2014. La restauración ecológica en Colombia. In: CIFOR Occasional Paper No. 107. Center for International Forestry Research (CIFOR).

Murcia, C., Guariguata, M.R., Andrade, Á., Andrade, G.I., Aronson, J., Escobar, E.M., Etter, A., Moreno, F.H., Ramírez, W., Montes, E., 2016. Challenges and prospects for scaling-up ecological restoration to meet international commitments: Colombia as a case study. Conserv. Lett. 9 (3), 213–220. https://doi.org/10.1111/conl.12199.

Murcia, C., Guariguata, M.R., Quintero-Vallejo, E., Ramírez, W., 2017. La restauración ecológica en el marco de las compensaciones por pérdida de biodiversidad en Colombia: Un análisis crítico. In: CIFOR Occasional Paper No. 176. Center for International Forestry Research (CIFOR). https://doi.org/10.17528/cifor/006611.

Nelson, C.R., Hallett, J.G., Romero Montoya, A.E., Andrade, A., Besacier, C., Boerger, V., Bouazza, K., Chazdon, R., Cohen-Shacham, E., Danano, D., Diederichsen, A., Fernandez, Y., Gann, G.D., Gonzales, E.K., Gruca, M., Guariguata, M.R., Gutierrez, V., Hancock, B., Innecken, P., Katz, S.M., McCormick, R., Moraes, L.F.D., Murcia, C., Nagabhatla, N., Pouaty Nzembialela, D., Rosado-May, F.J., Shaw, K., Swiderska, K., Vasseur, L., Venkataraman, R., Walder, B., Wang, Z., Weidlich, E.W. A., 2024. Standards of practice to guide ecosystem restoration – a contribution to the United Nations decade on ecosystem restoration 2021–2030. FAO, SER, & IUCN CEM. https://doi.org/10.4060/cc9106en.

Palacios, M.M., Carnell, P.E., Waryszak, P., Trevathan-Tackett, S.M., Masqué, P., Macreadie, P.I., 2021. Blue carbon drawn down by restored mangrove forests improves with age. J. Environ. Manag. 306, 114301. https://doi.org/10.1016/j.jenvman.2021.114301.

Peña-González, N., 2016. Análisis de la información bibliográfica sobre monitoreo a la restauración ecológica y restauración activa y pasiva en el territorio continental de la nación. Instituto Alexander von Humboldt. http://hdl.handle.net/20.500.11761/9655.

Peña-González, N., Aguilar-Garavito, M., Rubio, J., 2018. Actualización y ajustes de base de datos que compila publicaciones y proyectos de restauración ecológica a nivel nacional. In: Informe final de consultoría para la Red Colombiana de Restauración Ecológica (REDCRE). REDCRE, Bogotá, Colombia.

Presidencia de la República, 2010. Plan Nacional de Desarrollo 2010-2014. Prosperidad para todos. https://www.dnp.gov.co/plan-nacional-desarrollo/Paginas/prosperidad-para-todos-2010-2014-juan-manuel-santos.aspx.

Presidencia de la República, 2014. Plan Nacional de Desarrollo 2014-2018. Todos por un nuevo país. https://www.dnp.gov.co/plan-nacional-desarrollo/Paginas/todos-por-un-nuevo-pais-2014-2018-juan-manuel-santos.aspx.

Presidencia de la República, 2018. Plan Nacional de Desarrollo 2018-2022. Pacto por Colombia, pacto por la equidad. https://www.dnp.gov.co/plan-nacional-desarrollo/Paginas/plan-nacional-de-desarrollo-2018-2022.aspx.

Presidencia de la República, 2022. Plan Nacional de Desarrollo 2022-2026. El Plan de la Gente. https://www.dnp.gov.co/plan-nacional-desarrollo/pnd-2022-2026.

Rodríguez-Rodríguez, J.A., 2022. La restauración de los manglares en Colombia. Técnicas, saberes y experiencias. INVEMAR.

Rodríguez-Rodríguez, J.A., Mancera-Pineda, J.E., Tavera, H., 2021. Mangrove restoration in Colombia: trends and lessons learned. For. Ecol. Manag. 496, 119414. https://doi.org/10.1016/j.foreco.2021.119414.

SERA, 2018. National standards for the practice of ecological restoration in Australia. Society for Ecological Restoration Australasia (SERA). https://www.seraustralasia.com/standards/National%20Restoration%20Standards%202nd%20Edition.pdf.

Serrano, O., Gómez-López, D.I., Sánchez-Valencia, L., et al., 2021. Seagrass blue carbon stocks and sequestration rates in the Colombian Caribbean. Sci. Rep. 11, 11067. https://doi.org/10.1038/s41598-021-90544-5.

Society for Ecological Restoration International, 2004. The SER International primer on ecological restoration. Society for Ecological Restoration International. Retrieved from https://www.ser.org.

Torres Romero, F., Avella, A.M., Villota, L.A., Torres, S., Gómez, W., Díaz, J.E., Miranda, B., 2016. Avanza el plan piloto de restauración ecológica del bosque seco tropical (Technical Report). Fundación Natura. https://doi.org/10.13140/RG.2.2.20425.54888.

Torres Romero, F.J., 2020. Plan de restauración ecológica de bosque seco tropical de la central hidroeléctrica El Quimbo, Huila, Colombia. In: Leguízamo Barbosa, En A. (Ed.), Historia y aportes de la ingeniería forestal en Colombia, Volumen III. Asociación Colombiana de Ingenieros Forestales (ACIF), pp. 424–431.

UN, 2024. UN Decade on Restoration. https://www.decadeonrestoration.org/ (Accessed: 2 April 2024).

WRI, 2024. Initiative 20 x 20. https://initiative20x20.org/home (Accessed: 16 July 2024).