Received: 17 October 2019 | Revised: 3 April 2020 | Accepted: 23 April 2020
DOI: 10.1002/ppp3.10113

REVIEW

Plants People Planet PPP Open Access

Building a socio-ecological monitoring platform for the comprehensive management of tropical dry forests

Natalia Norden[1] | Roy González-M.[1] | Andrés Avella-M.[1,2] | Beatriz Salgado-Negret[3,4] | Carolina Alcázar[1] | Susana Rodríguez-Buriticá[1] | José Aguilar-Cano[1] | Carolina Castellanos-Castro[1] | Jhon J. Calderón[5] | Paula Caycedo-Rosales[6] | Hermes Cuadros[7] | Angélica Díaz-Pulido[1] | Zoraida Fajardo[8] | Rebeca Franke-Ante[9] | Daniel H. García[1] | Mailyn A. González[1] | Alma Hernández-Jaramillo[10] | Álvaro Idárraga-Piedrahita[11,12] | René López-Camacho[2] | Sindy J. Martínez-Callejas[1] | Jhon Nieto[1] | Camila Pizano[13] | Gina Rodríguez[14] | Alba M. Torres[15] | Hernando Vergara[16] | Hernando García[1]

[1]Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Bogotá, Colombia
[2]Proyecto Curricular de Ingeniería Forestal y Maestría en Manejo Uso y Conservación, Facultad de Medio Ambiente y Recursos Naturales, Universidad Distrital Francisco José de Caldas, Bogotá, Colombia
[3]Departamento de Biología, Universidad Nacional de Colombia, Bogotá, Colombia
[4]Grupo de Investigación en Química y Biología, Universidad del Norte, Barranquilla, Colombia
[5]Asociación GAICA, Pasto, Colombia
[6]Fundación Biodiversa Colombia, Bogotá, Colombia
[7]Programa de Biología, Universidad del Atlántico, Barranquilla, Colombia
[8]Programa de Naciones Unidas para el Desarrollo, PNUD, Bogotá, Colombia
[9]Dirección Territorial Caribe, Parques Nacionales Naturales de Colombia, Santa Marta, Colombia
[10]Neotropical Primate Conservation Colombia, Bogotá, Colombia
[11]Instituto de Biología, Universidad de Antioquia, Medellín, Colombia
[12]Jardín Botánico de Medellín Joaquín Antonio Uribe, Medellín, Colombia
[13]Departamento de Biología, Facultad de Ciencias Naturales, Universidad Icesi, Cali, Colombia

Societal Impact Statement

Tropical dry forests (TDF) underpin the wellbeing of millions, mostly rural populations; yet have suffered from severe clearing in Colombia, triggering cascading effects such as desertification. By engaging scientists, society, and institutions in the establishment of platforms for monitoring biodiversity and ecosystem functioning, crucial knowledge gaps will be bridged, helping to find a path toward sustainable development. Science-led but socially and economically anchored information on biodiversity will help to incorporate nature's contributions to people into the society's cultural values. Ultimately, these transformative actions will translate into the comprehensive management of TDF through a greater impact in decision making.

Summary

Thousands of permanent plots have been established across the tropics with the purpose of monitoring tree communities. Research outcomes from these platforms, however, have been mainly directed toward the academic community, and their contribution to society has been limited so far. Here, we show how generating robust data on biodiversity has supported decision making in Colombian tropical dry forests (TDF), where less than 8% of their original cover remains. As a first step to build a national dialogue around the critical status of this ecosystem, a national collaborative network on TDF research and monitoring was born in 2014, the Red de Investigación y Monitoreo del Bosque Seco Tropical en Colombia (Red BST-Col). Our main goal is to generate scientifically sound information that feeds into the comprehensive management of this ecosystem. To do so, a set of biodiversity monitoring platforms has been established

This work is the result of the *Red de Investigación y Monitoreo del Bosque Seco Tropical en Colombia* (Red BST-Col), a collaborative network that includes the author group listed above.

[14]Fundación Ecosistemas Secos de Colombia, Bogotá, Colombia

[15]Departamento de Biología, Universidad de Valle, Cali, Colombia

[16]Departamento de Biología, Universidad del Cauca, Popayán, Colombia

Correspondence
Natalia Norden, Programa Ciencias Básicas de la Biodiversidad, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Carrera 1 #16-20, Bogotá, Colombia. Email: nnorden@humboldt.org.co

Funding information
Ministerio de Ambiente y Desarrollo Sostenible de Colombia; United Nations Development Programme; Global Environmental Facility; Inter-American Development Bank, Grant/Award Number: ATN/BD-15408-CO

[Correction added on 10 July 2020, after first online publication: the author names 'José R. Aguilar-Cano' and 'Rebecca Franke-Ante' have been changed to 'José Aguilar-Cano' and 'Rebeca Franke-Ante' in the author list.]

across the country, which have already served to answer socio-ecological questions related with deforestation drivers, citizen science, or the valuation of ecosystem services. Overall, this research agenda has nurtured the four lines that underpin the *Program for the comprehensive management of dry forests in Colombia* (knowledge management, preservation, restoration, and sustainable use), formulated by the Humboldt Institute, the United Nations Development Programme, and the Ministry of Environment in 2019. Many challenges are ahead, however, for a complex territory where multiple social actors and productive sectors coexist. The ultimate goal is to integrate all the dimensions of biodiversity to achieve a synthetic understanding of the functioning of the most endangered ecosystem in Colombia, and its relationship with local communities' wellbeing.

KEYWORDS
biodiversity, biodiversity monitoring platforms, Colombia, comprehensive management, local communities, permanent plots, tropical dry forests

1 | INTRODUCTION

Tropical forests harbor the Earth's highest biodiversity and play a central role in global atmospheric cycles (Gentry, 1988; Malhi et al., 2008). Scientists have been attracted by their complexity for centuries, addressing a wide variety of ecological questions regarding patterns of species distribution, as well as all kinds of biotic and abiotic interactions (e.g., Corlett, 2014; Janzen, 1970). A large proportion of research has concentrated its efforts on plant ecology, as trees provide habitat structure for many other plants and trophic levels. As a result, biologists have established thousands of permanent plots for monitoring tree communities across the tropics during the last decades (Aderson-Teixeira et al., 2015; Phillips et al., 2009; ter Steege et al., 2013). The high versatility of permanent plots has promoted the development of several networks, which are now instrumental for evaluating socially relevant issues such as tropical forests' contribution to climate change mitigation (Brienen et al., 2015; Chave et al., 2008). However, the extent to which this knowledge has had a direct contribution to society is less clear (Pascual et al., 2017).

To address this issue, permanent plots can be approached as biodiversity monitoring platforms, where repeated tree surveys in one or a set of plots are combined with the monitoring of other organisms, and also include functional, environmental, and landscape characterizations. In that sense, these platforms become a powerful tool to support decision making related to environmental problems by promoting a synthetic understanding of ecological systems. Moreover, because they are conceived as a continuous endeavor, biodiversity monitoring platforms may encourage collaboration between different actors, thereby articulating benefits to people (Sierra et al., 2017). In the face of rapid forest loss and its critical consequences for biodiversity and ecosystem functioning, scientists, practitioners, and rural dwellers must work hand-in-hand to impact policies related to forest conservation and sustainable management. This goal may be partly reached by going beyond the traditional scope of permanent plots, and transition from purely academic approaches for monitoring biodiversity to shared platforms assessing socio-ecological resilience (Díaz et al., 2011, 2018). By involving social actors, plot-based networks may provide not only the information needed to improve ecological integrity but also the means to enhance knowledge appropriation and thereby evolve toward a comprehensive management of transformed landscapes (Evans & Guariguata, 2008).

Here, we show how the establishment of biodiversity monitoring platforms across Colombian tropical dry forests (TDF) has been the first step to build a national dialogue engaging scientists, society, and institutions. We emphasize on the importance of strengthening a collaborative network to increase our understanding of this critical ecosystem, and we illustrate, through examples, how knowledge generation on biodiversity has supported decision making at local, regional, and national levels.

2 | COLOMBIAN TROPICAL DRY FORESTS: AN OUTSTANDING CHALLENGE

Nowhere is it more important to find the connection among science, policy and people than in drylands, one of the most endangered biomes worldwide (Bastin et al., 2017). Among Neotropical drylands, a large fraction corresponds to TDF, an ecosystem characterized by a high variation in floristic composition at continental (DryFlor, 2016) and regional scales (González-M. et al., 2018), and harboring a great number of endemic species (Linares-Palomino, Oliveira-Filho, & Pennington, 2011). TDF play a key role in climate regulation and soil fertility maintenance, and are critically important for watershed protection, an essential service in an ecosystem where water scarcity is the rule (Maass et al., 2005). In addition, it provides tangible goods for millions, underpinning the wellbeing and employment of rural populations through the supply of food and fuel wood (Blackie et al., 2014). Despite their pivotal role in society, TDF have suffered from severe and widespread clearing across South America (Portillo-Quintero & Sánchez-Azofeifa, 2010). On top of this, converted lands are under desertification threat as droughts are becoming longer and more frequent, a byproduct of climate change (García, Corzo, Isaacs, & Etter, 2014; Huang, Yu, Guan, Wang, & Guo, 2016). Given this scenario, there is an urgent need of thoroughly evaluating the resilience of TDF and their contribution for supporting the livelihoods of local communities in fast-changing environments.

Addressing this challenge is an even more demanding task in Colombia, where less than 8% of the original area covered by this ecosystem remains, and only 5% of remnants are protected (García et al., 2014). Land use conversion has been mainly driven by cattle ranching and agriculture, and today's forest fragments are threatened by the development of megaprojects such as roads, hydroelectric dams, or mining (González-M. et al., 2018). Above all, many TDF areas have been the arena of a complex, long-lasting armed conflict, which has either prevented or promoted deforestation, depending upon the identity of armed actors and the geography of the region (Dávalos, 2001; Negret et al., 2019). This situation led the Colombian government to categorize TDF as a critically endangered ecosystem (Etter, Andrade, Saavedra, Amaya, & Arévalo, 2017), a strategy to prioritize actions in favor of the preservation and restoration of forest remnants (DNP, 2010). Although the mandate is clear, building a consensus among the whole spectrum of stakeholders and the academic community is a huge challenge. Hope is set on the use of science-led but socially and economically anchored information on biodiversity. A thorough assessment of the impact of human-driven activities on biodiversity and ecosystem functioning will help to identify potential tipping points from which socio-ecological resilience will no longer be possible. However, for this information to be relevant, a multidisciplinary analysis of the economic, political, and social barriers hampering conservation approaches is needed, as well as a constant dialogue among the different actors coexisting in the territory (Díaz et al., 2011).

3 | COMPREHENSIVE MANAGEMENT OF TDF BUILT UPON PERMANENT PLOTS

Ten years ago, TDF in Colombia were poorly known, to the point that their distribution in the country was not well documented (Etter, McAlpine, & Possingham, 2008; Figure 1). In 2014, over 20 academic and governmental institutions, as well as environmental and social NGOs, joined forces to increase our knowledge of this ecosystem. This initiative helped to consolidate a national collaborative network on TDF research and monitoring, the *Red de Investigación y Monitoreo del Bosque Seco Tropical en Colombia* (Red BST-Col), whose main goal is to generate scientifically sound information that feeds into strategies for a comprehensive management of TDF (Figure 1). During that first meeting, a roadmap was developed to identify short-, medium-, and long-term priorities (Pizano, González-M., Hernández-Jaramillo, & García, 2017). The Alexander von Humboldt Biological Resources Research Institute (Humboldt Institute), an organization facilitating communication between scientists and decision makers in Colombia, fulfilled the pressing task of producing a detailed map of TDF current distribution and conservation status (Instituto umboldt, 2014; Figure 2a). This map, which combined satellite imagery with extensive ground validations, provided the first rigorous depiction of the extent of TDF dire condition, enhancing its visibility as an endangered ecosystem on social and political arenas.

The mid-term priority of this research agenda was to establish a comprehensive, nation-wide biodiversity monitoring platform allowing to address issues related to the science–society boundary. To do so, the Red BST-Col established a set of platforms across the country that included flora, fauna, and ecosystem processes assessments (Figure 2b,c). Although this approach has already served to answer several socio-ecological questions related to deforestation drivers, biodiversity use, or ecosystem services valuation, these efforts are not enough in a complex territory where rural populations have lived for centuries and forest fragments are therefore embedded in productive landscapes. Preventing the loss of biodiversity and of ecological integrity has been hampered by the lack of an environmental legislation, specific to TDF. A robust policy associating the knowledge generated on this ecosystem for over almost a decade with its comprehensive management is crucial to regulate deforestation and forest degradation.

In view of this situation, in 2018–2019, the Humboldt Institute, in hand with the Ministry of Environment and Sustainable Development (MADS) and the United Nations Development Programme (UNDP), formulated the *National Program for the Comprehensive Management of Tropical Dry Forests in Colombia* (PNGIBST). The PNGIBST delineates an action plan with a horizon of 10 years, the main purpose of which is to promote the comprehensive management and ecological integrity of TDF through joint actions from academia, state government, NGOs, productive sectors, and civil society. This program, led by the Humboldt Institute and UNDP but built upon a participatory process involving regional stakeholders, is structured around four major topics: (a) *Knowledge management*, aiming to fill knowledge gaps and to catalyze knowledge appropriation about the state of biodiversity, its major threats and how it relates to ecosystem services, by combining academic expertise and local knowledge; (b) *Preservation*, the purpose of which is to achieve efficient conservation in the long term by identifying and managing top priority areas, as well as by integrating complementary conservation strategies that involve local communities; (c) *Restoration*, aiming for the recovery of degraded areas through participative processes prioritizing both passive and active restoration actions; and (d) *Sustainable use*, seen as a conservation strategy relying on the design and implementation

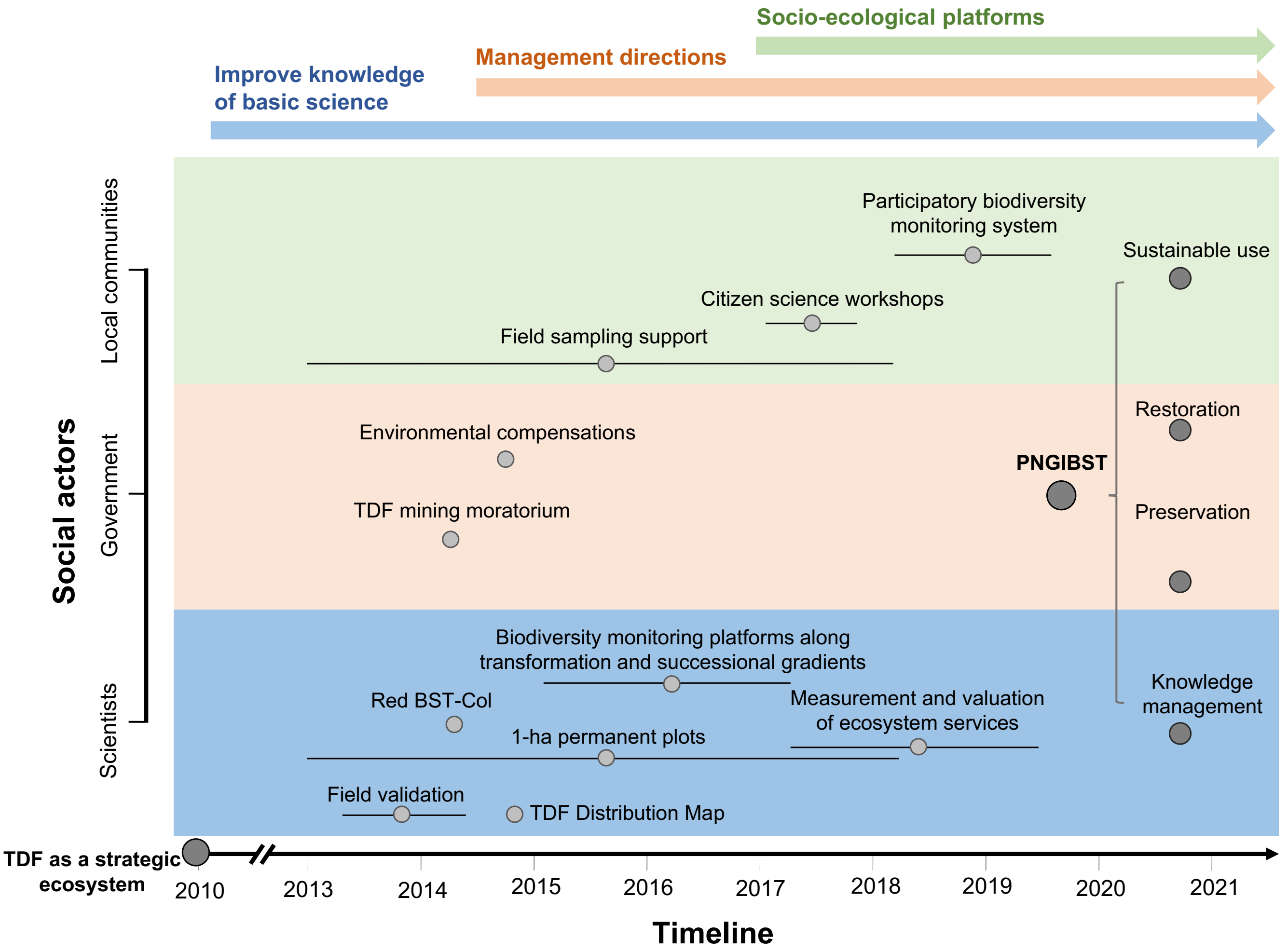

FIGURE 1 Timeline showing the benchmarking events that have shaped the agenda of tropical dry forests (TDF) in Colombia. Motivated by the declaration of TDF as a strategic ecosystem, the academic community established multiple biodiversity monitoring platforms across the country to increase our understanding on the functioning of this ecosystem. In parallel, the positioning of TDF as a critically endangered ecosystem encouraged the National Government to urge other initiatives that have contributed to its conservation. Although local communities have been involved since the beginning of this research agenda, nowadays, their engagement has been significantly strengthened through their participation in citizen science schemes. The National Program for the Comprehensive Management of TDF in Colombia (PNGIBST) will address issues relevant to all actors

of sustainable models of production and nature-based solutions to reach a balance between TDF ecosystem services and economic and socio-cultural interests. Here, we describe how the ongoing research agenda in TDF has nurtured each of these four guiding lines (Figure 3).

3.1 | Knowledge management

Among its first activities, the Red BST-Col initiated a thorough evaluation of the taxonomic, functional, and phylogenetic facets of plant communities through a set of sixteen 1-ha permanent plots established across different TDF regions, where 536 species belonging to 79 families were recorded (Figure 2b). This information has shown that species diversity, forest basal area, and canopy height decrease as drought and landscape transformation increase (González-M. et al., 2019). Data have also provided insights on patterns of TDF tree species' abundance and spatial distribution, showing that almost half of the species recorded in permanent plots are extremely rare and as much as 80% exhibit a restricted distribution (Norden et al., 2019). To trace the path from functional traits all the way to ecosystem functioning, and evaluate species responses to environmental gradients as well as their impact on ecosystem properties, leaf and wood anatomical traits have been sampled for a subset of 400 species. So far, functional data have been the basis to assess trait variation among tree species (Nieto et al., 2017; Pulido-Rodríguez, López-Camacho, Torres, Velasco, & Salgado-Negret, 2020). Further analyses will help to understand how plants cope with drought, and thereby predict TDF resilience in face of future climate change scenarios (Allen et al., 2017). Efforts are being made as well on the genetic dimension of biodiversity to disentangle TDF assembly from an evolutionary perspective. Tissues from all botanical samples have

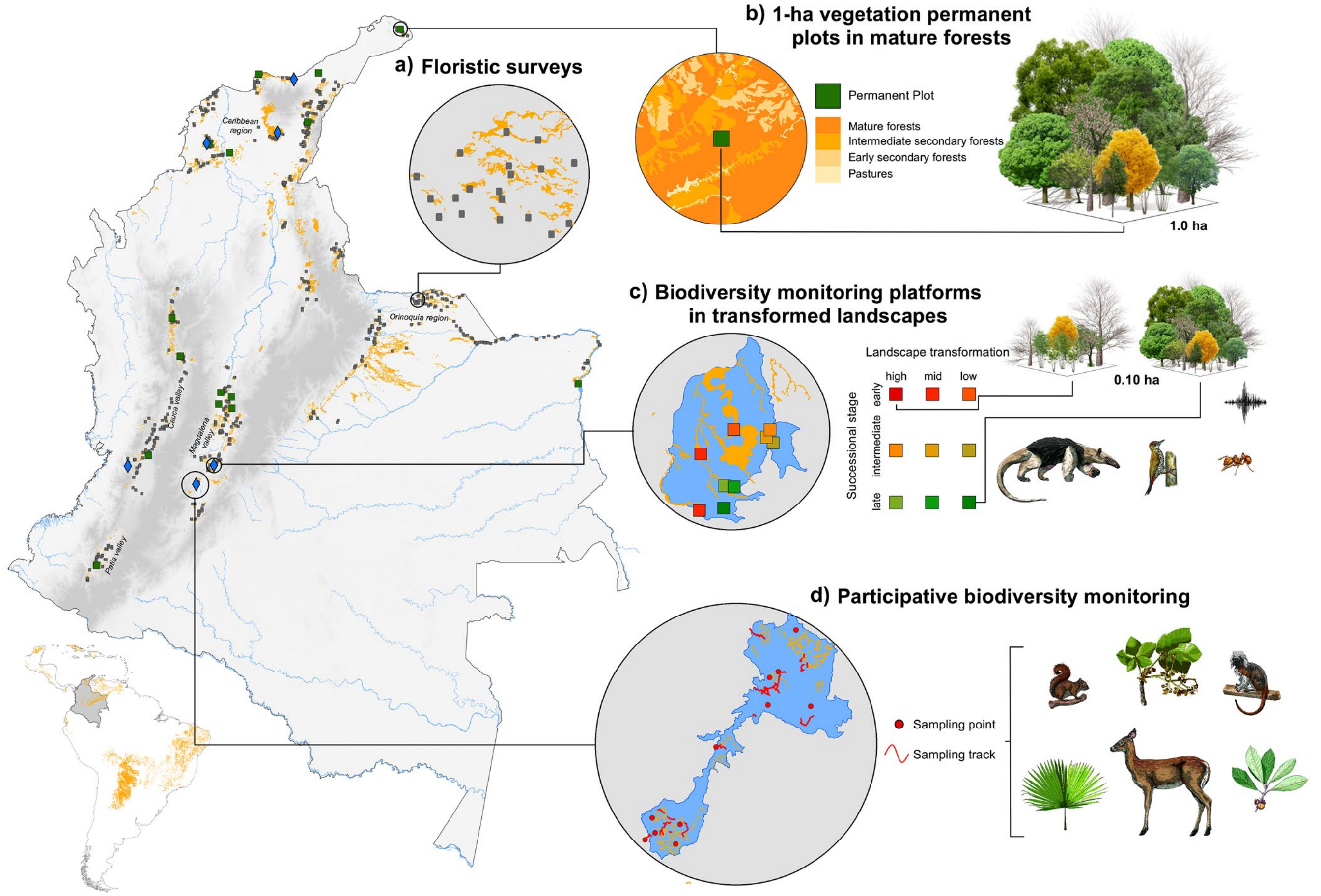

FIGURE 2 Description and locations of the different kinds of biodiversity monitoring platforms. (a) Validations points in 571 forest fragments that nurtured the map of tropical dry forests (TDF) distribution; (b) location of the sixteen 1-ha tree permanent plots established in mature forest fragments of TDF and including taxonomic, functional, and phylogenetic information for all tree species; (c) location of the nine biodiversity platforms for monitoring woody plants in nine to twelve 0.1 ha plots, birds, terrestrial vertebrates, ants, and soundscape along gradients of landscape transformation and forest succession; (d) location of the three participatory monitoring platforms relying on tracks along different sampling points, where local communities evaluated several fauna and flora species

been systematically collected with the purpose of obtaining a resolved phylogeny of TDF flora.

Because most TDF remnants are secondary forests with an uncertain ability to recover (González-M. et al., 2018), identifying relevant indicators for measuring the extent to which ecological integrity is jeopardized is a priority. To address this issue, nine biodiversity monitoring platforms were established across the country along gradients of landscape transformation and forest succession, and changes in tree, bird, terrestrial vertebrate, and ant communities were evaluated. Emphasis was put into acoustic ecology as it has the potential to be a great, novel asset for assessing forest conservation status (Rodríguez-Buriticá et al., 2019; Sueur, Pavoine, Hamerlynck, & Duvail, 2008). In addition, seedling dynamics are being monitored in two of these platforms to provide insights into the recovery potential of successional stands (Norden, Chazdon, Chao, Jiang, & Vílchez-Alvarado, 2009). Because forest cover is essential for people's wellbeing, there is a need to evaluate the link between ecosystem functioning and ecosystem services. Thus, processes such as carbon and nutrient cycling were assessed in two platforms to understand how these processes translate into people's benefits (Rivera-Sanín et al., 2019).

Knowledge has been disseminated through the publication of open-access books, manuals, guides, and non-academic papers (González-M., 2017; Hernández-Jaramillo et al., 2019; Pizano & García, 2014; Pizano et al., 2016, 2017). All the plant records collected in the field are available at the SIB-Colombia (Sistema de Información de la Biodiversidad; https://sibcolombia.net), a network of data on biodiversity, and the Colombian node of the GBIF network (Global Biodiversity Information Facility). Combined, this open-access approach has promoted an increased visibility and awareness of the critical status of TDF at local and national scales. Likewise, permanent plots are part of several collaborative networks (e.g., ForestPlot.NET, DryFlor, 2ndFOR), thereby contributing to an increased understanding of TDF in the Americas (DryFlor, 2016; Rozendaal et al., 2019). Overall, we expect the information generated to be at the center of strategies aiming to safeguard ecosystem

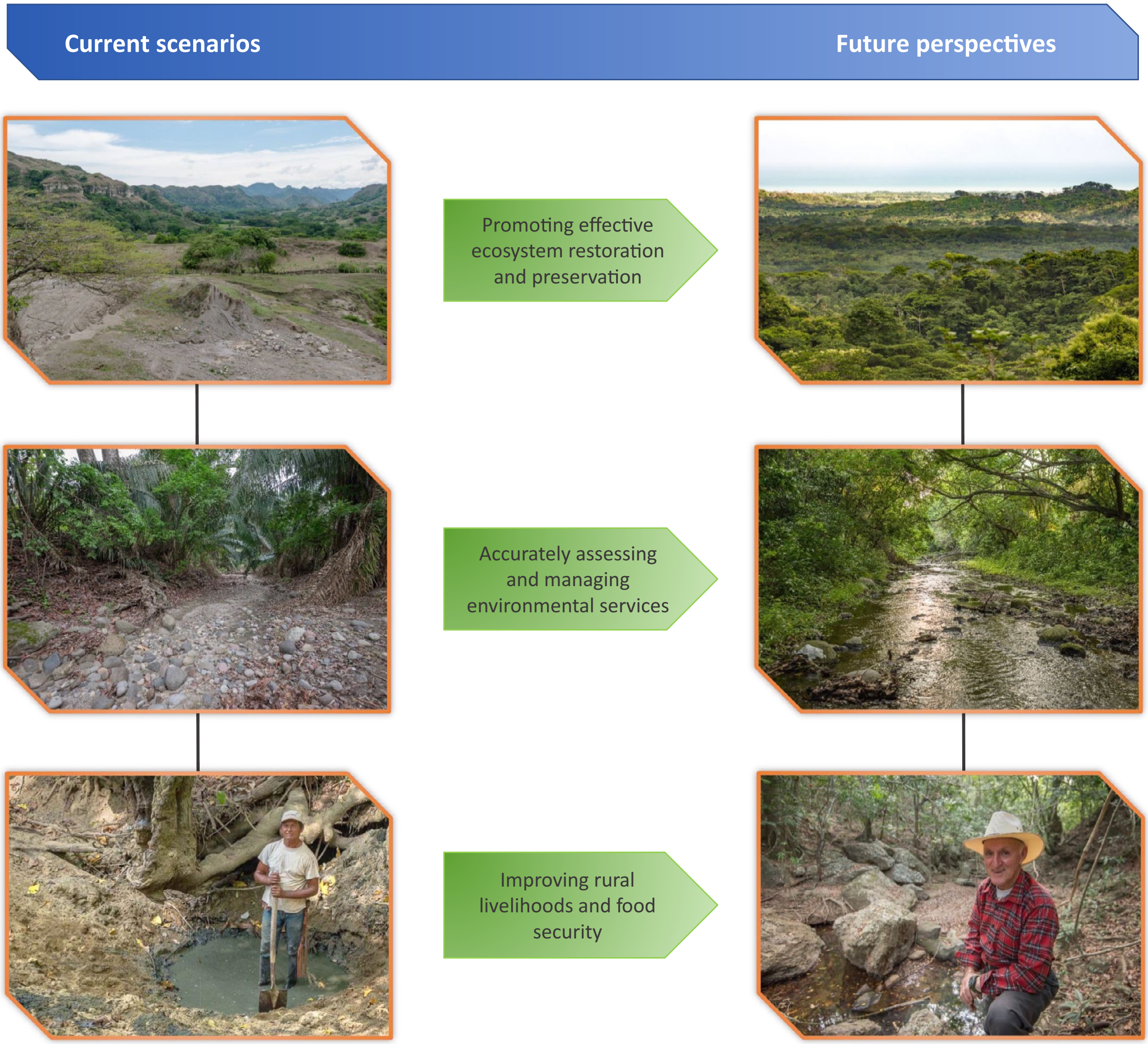

FIGURE 3 Current scenarios and future perspectives in Colombian tropical dry forests. The comprehensive management of this ecosystem will allow to enhance its ecological integrity through the effective preservation of strategic areas, complemented by restoration projects. This will be accompanied by the improvement in the provision of ecosystem services, in particular those related with water regulation, which is the most scare resource during the dry season. Ultimately, the optimization of land management will support human wellbeing and increase food security. Photos by Felipe Villegas

integrity while promoting rural sustainable development through alternative management practices (Díaz et al., 2011).

3.2 | Preservation

Given the extent of deforestation in Colombian TDF, targeting efforts to preserve the most conserved fragments of this ecosystem is crucial. The map of TDF current distribution revealed the extent of cover loss, which prompted the National Government to declare several protected areas. This is the case, for instance, of two areas in the Caribbean, ranging from a few hundred to a few thousand hectares, and targeting the preservation of the cotton-top tamarin, *Saguinus oedipus*, an endemic and endangered species of the region. Likewise, there is an ambitious plan in the Magdalena Valley to protect the best relicts of TDF in Colombia through the combination of strict land use planning and preservation strategies in an area of 36,000 ha. The map has also been instrumental to define the limits of a mining moratorium, where all the licenses for mining exploration and exploitation have been suspended while environmental authorities identify and declare the strategic areas that need protection. Thanks to this measure, gold-mining and sand exploitation projects threatening TDF patches in Northern Colombia have been interrupted.

However, because most remnants occur in private lands and are experiencing strong anthropogenic pressures (DryFlor, 2016; González-M. et al., 2018), these endeavors might be insufficient if complementary conservation strategies are not taken into account. In this sense, local conservation agreements may be a solution to protect the maximum number of forest patches and thereby reach a comprehensive management for these landscapes. Also, as 35% of the red-listed TDF species are found outside protected areas, and half of these occur in heavily human-impacted landscapes, we need to move from area-based to species-based conservation measures (Castellanos-Castro, Sofrony, Higuera, Peña y Valderrama, 2017). To do so, under the umbrella of the National Strategy for Plant Conservation (Samper & García, 2001) and in compliance with the Convention on Biological Diversity, 184 TDF plant species from the Caribbean and Orinoquia regions were prioritized for conservation, and another 10 are being preserved ex-situ as a result of an initiative led by the National Network of Botanical Gardens (Castellanos-Castro, Córdoba, López-Gallego, & Toro, 2017).

Another way of linking the knowledge generated on TDF to conservation goals is through tree permanent plots, which provide essential insights into forests' future (Beckage et al., 2008). In National Parks, for instance, the staff's involvement in the establishment of plots located in four protected areas opened the door to the integration of these methodologies into their monitoring procedures with the intent of identifying threats and mitigating human impacts. The outcomes of this initiative are already noticeable. For instance, available data on tree recruitment and mortality in a plot located at the Macuira National Park, Northern Colombia, suggested that grazing by goats is jeopardizing seedling regeneration in many of the patches occurring in the area. Also, species lists arising from these inventories turned out to be extremely useful for the ex-situ conservation of plant species under threat or with restricted range. Specifically, thanks to an agreement between the Humboldt Institute and Royal Botanic Gardens, Kew, living seeds of over 100 tree species have been collected in the surroundings of permanent plots, and stored in a living Seed Bank collection located at the Humboldt Institute.

3.3 | Restoration

Permanent plots established along successional gradients and/or across restoration treatments are a great asset for evaluating forest recovery (Crouzeilles et al., 2017). In particular, increased knowledge on seedling regeneration may guide restoration strategies through the identification of species with functional strategies to deal with factors predicted to be more pressing in the future, such as droughts or increased temperatures (Martínez-Garza, Bongers, & Poorter, 2013). Although the Red BST-Col includes dozens of tree and seedling plots established in secondary forests, this information has yet to nurture the design of restoration projects. Integrating functional, genetic, and population dynamics data should also improve the effectiveness of restoration actions. Such a challenge may be facilitated by creative initiatives, such as Diversity for Restoration (D4R), an online decision-support tool developed to assist species selection during restoration efforts (Thomas et al., 2017). Its algorithm evaluates the most appropriate species to sow under different environmental conditions (e.g., drought, fires, degraded soils) by integrating information on functional traits, genetic quality of seed sources, and restoration targets. For instance, *Astronium graveolens* and *Bursera simaruba* are good candidates for areas experiencing extreme droughts as they show high phenotypic plasticity. Instead, *Muntigia calabura* and *Croton hibiscifolius* exhibit acquisitive traits allowing them to rapidly increase forest cover when soils are degraded.

In addition, plot-based information may provide metrics characterizing undisturbed, reference forests in terms of species composition, biomass stocks, and overall forest structure. This information, in turn, can be translated into relevant ecological indicators supporting restoration strategies. For instance, a large-scale restoration project aiming to restore ~11,000 ha of TFD in the Magdalena Valley is catalyzing forest recovery based on a rigorous experimental framework. Species selection was defined based on the establishment of 70 permanent and temporal plots strategically located to encompass floristic variation across the landscape (Avella-M., 2019). This large-scale initiative, and a similar one in the Magdalena Valley (Corzo, Portocarrero, & Silva, 2017), are linked to the construction of hydroelectric dams, and are the result of government compensations schemes ensuring that environmental impacts resulting from development projects are compensated through conservation actions (MADS, 2012; Figure 1). These examples illustrate how instruments to offset large impacts in vulnerable ecosystems can by an opportunity to put ground information arising from tree permanent plots to practical use.

3.4 | Sustainable use

Paradoxically, the gradual disappearance of TDF has boosted the creation of innovative programs aiming to change the traditional view of resource extraction and exploitation toward a more sustainable use of natural resources. So far, 362 plant species have been identified as having different uses (e.g., food, medicinal, craftwork, shade in pastures, fodder; López-Camacho, Sarmiento, Barrero, Gallego, & Cavelier, 2019). These initiatives have provided an added value to biodiversity-based economies and go hand-in-hand with human development and wellbeing.

The sustainable use of biodiversity requires a thorough characterization of population dynamics. As a first step in this direction, and as part of a UNDP project funded by the Global Environmental Facility, the Humboldt Institute has led a citizen science initiative in three contrasting territories of TDF. This was accomplished through gatherings of different institutions, smallholders, and local policymakers, which promoted knowledge exchange and capacity building among participants. As a result, inhabitants are monitoring six species of plants and three species of animals that are potentially useful or ecologically important (Figure 2d). By delimiting trails and tagging trees during these activities, local dwellers have now reported low population densities for some target species, and identified other potential sources of income related to rural tourism and bird watching. The whole process was accompanied by the publication of nature guides customized for local users (Hernández-Jaramillo et al., 2019). As part of the same project, UNDP launched the initiative "Products of Peace", whose goal is to connect small producers from Montes de María, in the Caribbean region, with entrepreneurs that value biodiversity. Overall, these actions promoted knowledge appropriation among local communities and raised awareness about the contribution of TDF biodiversity to people's wellbeing. Their big success partly came from previous cooperation between local communities and scientists during the setup and monitoring of biodiversity platforms (Figure 2d), which allowed extended and genuine co-working between them. Together, we expect these activities to generate changes in local practices, thereby promoting sustainability and reducing deforestation at the landscape level.

In sum, *knowledge management*, *preservation*, *restoration*, and *sustainable use* will result in the comprehensive management of TDF only if these guiding lines provide insights to accurately assess and manage nature's contributions to people, and thereby translate into an improvement of rural livelihood and food security (Figure 3). In the aftermath, an ultimate goal is to have an impact on risk management. Specifically, the development of mitigation measures and adaptation to climate change are critically important issues in the drylands (Blackie et al., 2014).

4 | FUTURE PERSPECTIVES

Colombia is currently in a postwar phase, after five decades of internal conflict, which was expected to bring positive social change, especially in rural areas previously dominated by the FARC guerrillas (Sierra et al., 2017). The power vacuum left by this armed group, however, has opened the door to the expansion of illegal activities, aggravating deforestation rates in many regions (Negret et al., 2019). TDF are not immune to this issue. Many challenges are ahead for an ecosystem that overlaps with areas of major rural and urban development in the country, with an estimated 25 million people living where TDF were once distributed (Pizano & García, 2014).

Although Colombia is now one of the Latin-American countries with more ecological information on TDF, promoted by a robust collaborative network, we still need to strengthen our knowledge on several issues. In particular, restoration practices must find new approaches to measure success that go beyond vegetation recovery and that rely on a holistic understanding of this ecosystem. To that end, the academic community needs to prioritize landscape-level questions that include multiple trophic levels as well as different ecosystem processes (Young, Petersen, & Clary, 2005). Among the main gaps identified are the effect of defaunation on ecosystem functioning, fire ecology and management, and the response of soil biota to land use. Also, we need to deepen our understanding on TDF responses to future climatic change scenarios. Although flora and fauna occurring in this ecosystem are adapted to drought, species might be at the limit of their thermic tolerance and it remains uncertain whether increased climate severity will jeopardize their persistence (Allen et al., 2017). Another critical issue is the quantitative evaluation of the role of forest cover on water regulation and watershed protection. Water is probably the most essential resource for life, particularly in the drylands, yet we know relatively little about the mechanisms underlying the relation between forest cover and water provision (Portillo-Quintero, Sanchez-Azofeifa, Calvo-Alvarado, Quesada, & do Espirito Santo, 2015).

Bridging these knowledge gaps partly relies on the long-term monitoring of ecological platforms. To guarantee continuity in the measurements of permanent plots, nodes of the Red BST-Col have been created at each region, where universities, local NGOs, and government entities meet regularly (Pizano et al., 2017). Through these gatherings, participants are expected to adjust the priorities for each region, develop a plan for the long-term maintenance of biodiversity monitoring platforms, and explore new avenues of funding. For this to work properly, local communities should continue to be empowered, and take the lead in participative processes that allow them to incorporate nature's contributions to people into their cultural values (Pascual et al., 2017). In this sense, ecological questions should address vital aspects relating to socio-ecological resilience and adaptive capacity to global change. Specifically, understanding the economic consequences of TDF degradation for rural populations, and the co-design of alternative management practices that include cost–benefit analyses is a top priority. Also, we need to seek for new alternatives of biodiversity use, and engage into constructive discussions about actual or potential conflicts between biodiversity use and conservation goals. Evaluating the socio-economic implications of value chains based on biodiversity products will strengthen environmental appropriation and preserve traditional knowledge. These questions, however, should mostly arise from local communities and stakeholders, in alliance with regional environmental entities.

Overall, we expect these transformative actions to improve human wellbeing and result in greater impact in decision making at different levels. The long-term engagement of scientists, social, and institutional actors in the territory should help with this enduring challenge. We hope that the Program for the Comprehensive Management of TDF in Colombia will be the role model for the management of other strategic ecosystems that need attention in the tropics.

ACKNOWLEDGMENTS

This paper is the result of many years of collaborative work among members of the Red BST-Col. The research agenda in TDF would not have been possible without the hospitality and assistance of all the owners, administrators, and indigenous communities of all TDF areas that we visited. We warmly thank all the members of the Red BST-Col for their invaluable commitment. Financial support was provided by Ministerio de Ambiente y Desarrollo Sostenible (MADS) of Colombia, the United Nations Programme for Development and the Global Environmental Facility (Proyecto *Uso Sostenible y conservación de la biodiversidad en ecosistemas secos*), and the Inter-American Development Bank (Cooperation #ATN/BD-15408-CO). We are grateful to Toby Pennington and two anonymous reviewers for insightful comments on the manuscript.

AUTHOR CONTRIBUTION

HG, RG-M, NN, AA-M, SR-B, BS-N, MAG, AH-J, AD-P, PC-R, CC-C, CA, CP, and SM-C planned and designed research; RG-M, HG, NN, BS-N, JJC, HC, ZF, RF-A, AH-J, AI-P, RL-C, SM-C, CP, GR, AM-T, and HV coordinated data collection; RG-M, BS-N, NN, JRA-C, PC-R, ADP, DHG, MAG, AHJ, AIP, RLC, SJM, and JN performed field work; NN wrote the manuscript and all co-authors commented on the manuscript.

ORCID

Natalia Norden https://orcid.org/0000-0001-5207-312X
Roy González-M. https://orcid.org/0000-0002-4346-998X
Beatriz Salgado-Negret https://orcid.org/0000-0002-3103-9878
Susana Rodríguez-Buriticá https://orcid.org/0000-0001-8175-1057
José R. Aguilar-Cano https://orcid.org/0000-0002-9997-1370
Carolina Castellanos-Castro https://orcid.org/0000-0002-5552-2506
Jhon J. Calderón https://orcid.org/0000-0001-7128-8310
Angélica Díaz-Pulido https://orcid.org/0000-0003-4166-4084
Mailyn A. González https://orcid.org/0000-0001-9150-5730
Álvaro Idárraga-Piedrahita https://orcid.org/0000-0002-4823-8849
René López-Camacho https://orcid.org/0000-0003-2026-0371
Sindy J. Martínez-Callejas https://orcid.org/0000-0001-7204-2005
Camila Pizano https://orcid.org/0000-0003-4124-1348

REFERENCES

Allen, K., Dupuy, J. M., Gei, M. G., Hulshof, C., Medvigy, D., Pizano, C., ... Powers, J. S. (2017). Will seasonally dry tropical forests be sensitive or resistant to future changes in rainfall regimes? *Environmental Research Letters*, *12*, 023001. https://doi.org/10.1088/1748-9326/aa5968

Anderson-Teixeira, K. J., Davies, S. J., Bennett, A. C., Gonzalez-Akre, E. B., Muller-Landau, H. C., Joseph Wright, S., ... Zimmerman, J. (2015). CTFS-Forest GEO: A worldwide network monitoring forests in an era of global change. *Global Change Biology*, *21*, 528–549. https://doi.org/10.1111/gcb.12712

Avella-M., A., García-G, N., Fajardo-Gutiérrez, F., & González-Melo, A. (2019). Patrones de sucesión secundaria en un bosque seco tropical internandino de Colombia: Implicaciones para la restauración ecológica. *Caldasia*, *41*, 12–27. https://doi.org/10.15446/caldasia.v41n1.65859

Bastin, J.-F., Berrahmouni, N., Grainger, A., Maniatis, D., Mollicone, D., Moore, R., ... Castro, R. (2017). The extent of forest in dryland biomes. *Science*, *356*, 635–638. https://doi.org/10.1126/science.aam6527

Beckage, B., Osborne, B., Gavin, D. G., Pucko, C., Siccama, T., & Perkins, T. (2008). A rapid upward shift of a forest ecotone during 40 years of warming in the Green Mountains of Vermont. *Proceedings of the National Academy of Sciences of the United States of America*, *105*(11), 4197–4202. https://doi.org/10.1073/pnas.0708921105

Blackie, R., Baldauf, C., Gautier, D., Gumbo, D., Kassa, H., Parthasarathy, N., ... Sunderland, T. (2014). *Tropical dry forests: The state of global knowledge and recommendations for future research* (Vol. 2). CIFOR. Retrieved from http://agritrop.cirad.fr/578088/

Brienen, R. J., Phillips, O. L., Feldpausch, T. R., Gloor, E., Baker, T. R., Lloyd, J., ... Martinez, R. V. (2015). Long-term decline of the Amazon carbon sink. *Nature*, *519*, 344–348. https://doi.org/10.5521/ForestPlots.net/2014_4

Castellanos-Castro, C., Córdoba, D., López-Gallego, C., & Toro, L. (2017). Grupos de flora de interés en conservación: Zamias, Magnolias, palmas y especies endémicas. In L. A. Moreno, G. I. Andrade, & L. F. Ruíz-Contreras (Eds.), *Biodiversidad 2016: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 202). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2016/cap2/202/

Castellanos-Castro, C., Sofrony, C., Higuera, D., Peña, N. y Valderrama, N. (2017). Estrategia Nacional para la Conservación de Plantas. In L. A. Moreno, G. I. Andrade, & L. F. Ruíz-Contreras (Eds.), *Biodiversidad 2016: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 304). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2016/cap3/304/index.html

Chave, J., Condit, R., Muller-Landau, H. C., Thomas, S. C., Ashton, P. S., Bunyavejchewin, S., ... Losos, E. C. (2008). Assessing evidence for a pervasive alteration in tropical tree communities. *PLoS Biology*, *6*, e45. https://doi.org/10.1371/journal.pbio.0060045

Corlett, R. (2014). *The ecology of tropical East Asia*. Oxford, MS: Oxford University Press. https://doi.org/10.1093/oso/9780198817017.001.0001

Corzo, G., Portocarrero, M., & Silva, L. M. (2017). Compensaciones ambientales por pérdida de biodiversidad. In L. A. Moreno, G. I. Andrade, & L. F. Ruíz-Contreras (Eds.), *Biodiversidad 2016: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 403). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2016/cap4/403/index.html.

Crouzeilles, R., Ferreira, M. S., Chazdon, R. L., Lindenmayer, D. B., Sansevero, J. B. B., Monteiro, L., ... Strassburg, B. B. N. (2017). Ecological restoration success is higher for natural regeneration than for active restoration in tropical forests. *Science Advances*, *3*, e1701345. https://doi.org/10.1126/sciadv.1701345

Dávalos, L. M. (2001). The San Lucas mountain range in Colombia: How much conservation is owed to the violence? *Biodiversity & Conservation*, *10*, 69–78. https://doi.org/10.1023/A:101665101

Díaz, S., Pascual, U., Stenseke, M., Martín-López, B., Watson, R. T., Molnár, Z., ... Shirayama, Y. (2018). Assessing nature's contributions to people. *Science*, *359*, 270–272. https://doi.org/10.1126/science.aap8826

Diaz, S., Quetier, F., Caceres, D. M., Trainor, S. F., Perez-Harguindeguy, N., Bret-Harte, M. S., ... Poorter, L. (2011). Linking functional diversity and social actor strategies in a framework for interdisciplinary analysis of nature's benefits to society. *Proceedings of the National Academy of Sciences of the United States of America*, *108*(3), 895–902. https://doi.org/10.1073/pnas.1017993108

DNP. Departamento Nacional de Planeación. (2010). *Plan Nacional de Desarrollo Prosperidad para todos (2010–2014)*. República de Colombia. Retrieved from https://www.cna.gov.co/1741/articles-311056_PlanNacionalDesarrollo.pdf

DryFlor. (2016). Plant diversity patterns in neotropical dry forests and their conservation implications. *Science*, *353*, 1383–1387. https://doi.org/10.1126/science.aaf5080

Etter, A., Andrade, A., Saavedra, K., Amaya, P., & Arévalo, P. (2017). Estado de los ecosistemas colombianos: Una aplicación de la metodología de la Lista Roja de Ecosistemas ver. 2.0. *Informe Final*. Bogotá, Colombia: Pontificia Universidad Javeriana.

Etter, A., McAlpine, C., & Possingham, H. (2008). Historical patterns and drivers of landscape change in Colombia since 1500: A regionalized spatial approach. *Annals of the Association of American Geographers*, *98*, 2–23. https://doi.org/10.1080/00045600701733911

Evans, K., & Guariguata, M. R. (2008). Monitoreo participativo para el manejo forestal en el trópico: una revisión de herramientas, conceptos y lecciones aprendidas. CIFOR. Retrieved from https://www.cifor.org/publications/pdf_files/Books/BGuariguata0801S.pdf

García, H., Corzo, G., Isaacs, P., & Etter, A. (2014). Distribución y estado actual de los remanentes del Bioma de Bosque Seco Tropical en Colombia: Insumos para su gestión. In C. Pizano, & H. García (Eds.), *El Bosque Seco Tropical en Colombia* (pp. 228–251). Insituto Alexander von Humboldt: Bogotá.

Gentry, A. H. (1988). Patterns of plant community diversity and florisitic composition on environmental a geographical gradient. *Annals of Missouri Botanicals Garden*, *75*, 1–34.

González-M., R., García, H., Isaacs, P., Cuadros, H., López-Camacho, R., Rodríguez, N., … Pizano, C. (2018). Disentangling the environmental heterogeneity, floristic distinctiveness and current threats of tropical dry forests in Colombia. *Environmental Research Letters*, *13*, 045007. https://doi.org/10.1088/1748-9326/aaad74

González-M., R., Norden, N., Posada, J. M., Pizano, C., García, H., Idárraga-Piedrahita, A., … Salgado-Negret, B. (2019). Climate severity and land-cover transformation determine plant community attributes in Colombian dry forests. *Biotropica*, *51*, 826–838. https://doi.org/10.1111/btp.12715

González-M., R., Pizano, C., Aguilar, J., Aguirre, J., Barbosa, A., Castaño, A., … García, H. (2017). Monitoreo de la vegetación en los bosques secos de Colombia: Una herramienta para el análisis y la gestión integral de este ecosistema a escala de país. In L. A. Moreno, G. I. Andrade, & L. F. Ruíz-Contreras (Eds.), *Biodiversidad 2016: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 306). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2016/cap3/306/.

Hernández-Jaramillo, A., Achury, R., Aguilar, J., Arcila, L., Caycedo-Rosales, P., Díaz-Pulido, A., … González-M., R. (2019). *Bosque Seco Tropical: guía de especies*. Bogotá, Colombia: Programa de Naciones Unidas para el Desarrollo, Fondo Mundial para el Medio Ambiente, Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Ministerio de Ambiente y Desarrollo Sostenible. 212 pp.

Huang, J., Yu, H., Guan, X., Wang, G., & Guo, R. (2016). Accelerated dryland expansion under climate change. *Nature Climate Change*, *6*, 166. https://doi.org/10.1038/nclimate2837

Humboldt, I. (2014). *Distribución espacial del bosque seco tropical en Colombia. Instituto de Investigación de recursos Biológicos*. Alexander von Humboldt. Retrieved from http://www.humboldt.org.co/en/research/projects/developing-projects/item/158-bosques-secos-tropicales-en-colombia

Janzen, D. H. (1970). Herbivores and the number of tree species in tropical forests. *The American Naturalist*, *104*, 501–528. https://doi.org/10.1086/282687

Linares-Palomino, R., Oliveira-Filho, A. T., & Pennington, R. T. (2011). Neotropical seasonally dry forests: Diversity, endemism, and biogeography of woody plants. In R. Dirzo, H. S. Young, H. A. Mooney, & G. Ceballos (Eds.), *Seasonally dry tropical forests* (pp. 3–21). Washington, DC: Island Press. Center for Resource Economics.

López-Camacho, R., Sarmiento, C., Barrero, A. M., Gallego, B., & Cavelier, I. (2019). Especies útiles del bosque seco tropical: Usar para conservar. In L. A. Moreno, G. I. Andrade, & M. F. Gómez (Eds.), *Biodiversidad 2018: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 302). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2018/cap3/302/.

Maass, J. M., Balvanera, P., Castillo, A., Daily, G. C., Mooney, H. A., Ehrlich, P., … Sarukhán, J. (2005). Ecosystem services of tropical dry forests: Insights from long-term ecological and social research on the Pacific Coast of Mexico. *Ecology and Society*, *10*, 1–23. https://doi.org/10.5751/ES-01219-100117

MADS. Ministerio de Ambiente y Desarrollo Sostenible. (2012). *Manual para la asignación de compensaciones por pérdida de biodiversidad*. República de Colombia. 49 p. Retrieved from http://www.minambiente.gov.co/images/BosquesBiodiversidadyServiciosEcosistemicos/pdf/gestion_en_biodiversidad/180912_manual_compensaciones.pdf

Malhi, Y., Roberts, J. T., Betts, R. A., Killeen, T. J., Li, W., & Nobre, C. A. (2008). Climate change, deforestation and the fate of the Amazon. *Science*, *319*, 169–172. https://doi.org/10.1126/science.1146961

Martínez-Garza, C., Bongers, F., & Poorter, L. (2013). Are functional traits good predictors of species performance in restoration plantings in tropical abandoned pastures? *Forest Ecology and Management*, *303*, 35–45. https://doi.org/10.1016/j.foreco.2013.03.046

Negret, P. J., Sonter, L., Watson, J. E. M., Possingham, H. P., Jones, K. R., Suarez, C., … Maron, M. (2019). Emerging evidence that armed conflict and coca cultivation influence deforestation patterns. *Biological Conservation*, *239*, 108176. https://doi.org/10.1016/j.biocon.2019.07.021

Nieto, J., González-M., R., Medina, S., Aldana, A. M., Álvarez, E., & Avella, A., … Salgado-Negret, B. (2017). Diversidad functional en los bosques de Colombia. In L. A. Moreno, G. I. Andrade, & L. F. Ruíz-Contreras (Eds.), *Biodiversidad 2016: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 106). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2016/cap1/106/.

Norden, N., Chazdon, R. L., Chao, A., Jiang, Y. H., & Vílchez-Alvarado, B. (2009). Resilience of tropical rain forests: Tree community reassembly in secondary forests. *Ecology Letters*, *12*(5), 385–394. https://doi.org/10.1111/j.1461-0248.2009.01292.x

Norden, N., González-M., R., Avella, A., Castaño, C., Castellanos-Castro, C., Cuadrado, B., … García, H. (2019). Las plantas raras del bosque seco: Patrones de abundancia y distribución de las especies e implicaciones para su gestión. In L. A. Moreno, G. I. Andrade, & M. F. Gómez (Eds.), *Biodiversidad 2018: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 202). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2018/cap2/202/.

Pascual, U., Balvanera, P., Díaz, S., Pataki, G., Roth, E., Stenseke, M., … Yagi, N. (2017). Valuing nature's contributions to people: The IPBES approach. *Current Opinion in Environmental Sustainability*, *26*, 7–16. https://doi.org/10.1016/j.cosust.2016.12.006

Phillips, O. L., Aragao, L. E. O. C., Lewis, S. L., Fisher, J. B., Lloyd, J., Lopez-Gonzalez, G., … Torres-Lezama, A. (2009). Drought sensitivity of the Amazon rainforest. *Science*, *323*, 1344–1347. https://doi.org/10.1126/science.1164033

Pizano, C., & García, H. (Eds.). (2014). *El bosque seco tropical en Colombia*. Bogotá, Colombia: Instituto Alexander von Humboldt.

Pizano, C., González-M., R., López, R., Jurado, R., Cuadros, H., Castaño, A., … García, H. (2016). El bosque seco tropical en Colombia: Distribución y estado de conservación. In M. F. Gómez, L. A. Moreno, G. I. Andrade, & C. Rueda (Eds.), *Biodiversidad 2015: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 202). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2015/cap2/202.html.

Pizano, P., González-M., R., Hernández-Jaramillo, A., & García, H. (2017). Agenda de investigación y monitoreo en bosques secos de Colombia (2013–2015): Fortaleciendo redes de colaboración para su gestión integral en el territorio. *Biodiversidad en la Práctica*, *2*, 87–121.

Portillo-Quintero, C., Sanchez-Azofeifa, A., Calvo-Alvarado, J., Quesada, M., & do Espirito Santo, M. M. (2015). The role of tropical dry forests for biodiversity, carbon and water conservation in the neotropics: Lessons learned and opportunities for its sustainable management. *Regional Environmental Change*, *15*, 1039–1049. https://doi.org/10.1007/s10113-014-0689-6

Portillo-Quintero, C. A., & Sánchez-Azofeifa, G. A. (2010). Extent and conservation of tropical dry forests in the Americas. *Biological Conservation*, *143*, 144–155. https://doi.org/10.1016/j.biocon.2009.09.020

Pulido-Rodríguez, N., López-Camacho, R., Torres, J., Velasco, J., & Salgado-Negret, B. (2020). Traits and trade-offs of wood anatomy between trunks and branches in tropical dry forest species. *Trees*, *34*(2), 497–505. https://doi.org/10.1007/s00468-019-01931-5

Rivera-Sanín, F., González-M., R., Norden, N., Rodríguez-Buriticá, S., Avella, A., Garzón-Medina, C. A., … Mogollón, A. (2019). Valoración integral del bosque seco como herramienta para su conservación y gestión. In H. García & R. González-M. (Ed.), *Bosque Seco Colombia: Biodiversidad y Gestión* (pp. 26–27). Bogotá, Colombia: Instituto de Investigaciones de Recursos Biológicos Alexander von Humboldt.

Rodríguez-Buriticá, S., Savage, D., Caycedo, P., Acevedo-Charry, O., Isaza, C., Daza, J. M., … Colombiana, R. E. (2019). Paisajes sonoros de Colombia: La otra dimensión de la biodiversidad. In L. A. Moreno, G. I. Andrade, & M. F. Gómez (Eds.), *Biodiversidad 2018: Estado y Tendencias de la biodiversidad continental de Colombia* (Report no. 103). Bogotá, Colombia: Instituto Alexander von Humboldt. Retrieved from http://reporte.humboldt.org.co/biodiversidad/2018/cap1/103/.

Rozendaal, D. M. A., Bongers, F., Aide, T. M., Alvarez-Dávila, E., Ascarrunz, N., Balvanera, P., … Poorter, L. (2019). Biodiversity recovery of Neotropical secondary forests. *Science Advances*, *5*, eaau3114. https://doi.org/10.1126/sciadv.aau3114

Samper, C., & García, H. (Eds.). (2001). *Estrategia Nacional para la Conservación de Plantas*. Bogotá, Colombia: Instituto de Investigación de Recursos Biológicos Alexander von Humboldt, Red Nacional de Jardines Botánicos de Colombia, Ministerio del Medio Ambiente y Asociación Colombiana de Herbarios.

Sierra, C. A., Mahecha, M., Poveda, G., Álvarez-Dávila, E., Gutierrez-Velez, V. H., Reu, B., … Skowronek, S. (2017). Monitoring ecological change during rapid socio-economic and political transitions: Colombian ecosystems in the post-conflict era. *Environmental Science & Policy*, *76*, 40–49. https://doi.org/10.1016/j.envsci.2017.06.011

Sueur, J., Pavoine, S., Hamerlynck, O., & Duvail, S. (2008). Rapid acoustic survey for biodiversity appraisal. *PLoS One*, *3*, e4065. https://doi.org/10.1371/journal.pone.0004065

ter Steege, H., Pitman, N. C. A., Sabatier, D., Baraloto, C., Salomao, R. P., Guevara, J. E., … Silman, M. R. (2013). Hyperdominance in the Amazonian tree flora. *Science*, *342*, 1243092. https://doi.org/10.1126/science.1243092

Thomas, E., Alcázar, A., Moscoso, H. L. G., Osorio, L. F., Salgado-Negret, B., González, M., … Ramírez, W. (2017). The importance of species selection and seed sourcing in forest restoration for enhancing adaptive potential to climate change: Colombian tropical dry forest as a model. In L. Rodríguez & I. Anderson (Eds.), *The Lima declaration on biodiversity and climate change: Contributions from science to policy for sustainable development* (pp. 122–134). Technical series no.89. Montreal, Canada: Secretariat of the Convention on Biological Diversity. ISBN: 978-9292256531. Retrieved from http://www.diversityforrestoration.org/

Young, T. P., Petersen, D. A., & Clary, J. J. (2005). The ecology of restoration: Historical links, emerging issues and unexplored realms. *Ecology Letters*, *8*, 662–673. https://doi.org/10.1111/j.1461-0248.2005.00764.x

How to cite this article: Norden N, González-M. R, Avella-M. A, et al. Building a socio-ecological monitoring platform for the comprehensive management of tropical dry forests. *Plants, People, Planet*. 2020;00:1–11. https://doi.org/10.1002/ppp3.10113