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COMMENTARY

Young voices and visions for tropical restoration science in the UN Decade on Ecosystem Restoration

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1 | INTRODUCTION

Protecting ecosystems, in their current extent and function, is no longer sufficient to meet global conservation and sustainable development goals: we must also restore ecosystems to remedy past degradation (Gann et al., 2019; Leclère et al., 2020). Although ecosystem restoration is needed globally, focusing efforts on the tropics may provide the largest benefits to humans and nature (Strassburg et al., 2020). The tropics harbor a disproportionate amount of global "biodiversity hotspots" and therefore restoring habitat cover, connectivity, and quality in degraded tropical landscapes is critical to preventing species extinctions (Dutta et al., 2018; Newmark et al., 2017). Also, tropical restoration strategies that improve vegetation structure, functionality, and diversity can increase carbon sequestration and therefore contribute substantially to climate change mitigation strategies (Griscom et al., 2020). Additionally, ecosystem restoration in tropical landscapes can enhance water security (Ellison et al., 2017), improve water quality (Pires et al., 2017), facilitate climate change adaptation (Senior et al., 2019), and can contribute to income, consumption, and other dimensions of livelihoods and well-being (Bradbury et al., 2021).

Young people are frequently overlooked, undervalued, or left out from key stages of sustainable development, leading to disengagement, and possible failure of projects (Barraclough et al., 2021). This trend might become relevant, if not already, in research communities involving young voices in academia focusing on tropical restoration science. Young voices are needed when developing and implementing restoration initiatives because they embody and reflect a different social, cultural, political, and academic environment than those of academics at advanced stages of their careers. For instance, young academics are likely to spend substantially longer time in the field during their graduate research, allowing them increased ability to witness how restoration affects local ecosystems and people. This is relative to more senior academics who would have cumulatively spent longer time doing fieldwork but might not as they progress to senior academic positions. Today, young restoration researchers develop their perspectives considering contemporary worldviews in conservation, such as Recoverable Earth narratives versus Finite Earth narratives, that is, grounded adaptive action to restore nature for the better future of nature and people versus morally motivated conservation foregrounded in villainous and heroic roles and worrying change, and pragmatic ways of approaching conservation and

restoration in contrast with absolutist values (Jepson, 2019). This is a remarkable shift in ideals, when compared to relatively senior academics (senior in terms of age and time since graduating from a graduate program). The inclusion of young voices and visions in restoration science is, therefore, critical for a forward-looking and innovative development of this field.

Hence, successful restoration initiatives are increasingly recognizing the involvement of the younger generation, including those who are young in their academic careers (IUCN, 2017a, 2017b). For instance, involving young voices in restoration are a key component of the current UN Decade on Ecosystem Restoration (UNEP, 2021). However, the priorities, steps, and action points that young researchers envision for the UN Decade are largely unknown. This crucial information will guide restoration-focused science, policy, finance, and on-the-ground implementation of activities, fostering future leaders in the field of ecosystem restoration. Here, we aim to outline key visions that young researchers have for the future of tropical restoration science, supported by our own experiences as young restoration scientists and the findings from a survey that we deployed during an open format session at the annual meeting of the Association of Tropical Biology and Conservation 2021 (ATBC, 2021). We then provide key contributions that young researchers can make when doing impactful research. These contributions will advance the science of restoration ecology in the tropical biome and encourage more effective strategies in the UN Decade on Ecosystem Restoration.

2 | YOUNG VOICES IN AND VISIONS FOR TROPICAL RESTORATION SCIENCE SYMPOSIA

We define young voices in academia as voices of current graduate students (Master's level or doctoral students) or postdoctoral scientists within 1–2 years of completion of their doctorate degrees. We organized an open format session at the online ATBC 2021, titled "Young Voices in and Visions for Tropical Restoration Science" (ATBC, 2021). The aims of this session were as follows: (1) to provide a platform for doctoral students to showcase their research and visions for restoration science in tropical landscapes, (2) to build a community of young restoration scientists working toward a sustainable future, and (3) to present and share a vision for the future of tropical restoration science by including the wider community of young researchers. The session consisted of a panel of six doctoral candidates who presented case studies of restoration-focused research in the tropics. These case studies encompassed tropical mountain, agricultural, and forest landscapes and featured a range of methodologies that are advancing the field of restoration science, including the use of remote sensing and derived products, functional ecology, field-based data collection, and governance instruments. Lastly, each panelist presented their vision for the future of tropical restoration (Table 1). We deployed a 9-multiple choice question survey during the Q&A part of the session, asking respondents for important actionable steps in the UN Decade on Ecosystem Restoration, their vision for the future of tropical restoration science, and demographic information. We also provided the option to specify additional categories or ideas. We designed the survey based on our joint expertise and experience doing tropical restoration science research and using recent relevant literature (Aronson et al., 2020; Di Sacco et al., 2021; Gann et al., 2019; Osborne et al., 2021). We received 11 responses, nine of which were students (up to PhD) aged 18–35 years. The nationalities of the respondents included Brazilian, British, Dutch, German, Indian, Singaporean, Venezuelan, and Malaysian/French. The respondents researched in in Sri Lanka, Southeast Asia, West Africa, Old World tropical forests, Brazilian Atlantic Forest, India, the Andes, Australia, and Colombia. We acknowledge that our survey respondents were from a limited demographic base and therefore do not represent the beliefs and visions of all young restoration scientists. However, we use this information to outline broad trends and support the development of our five visions. We deployed the survey following review and approval by the Central University Research Ethics Committee (CUREC), based at the University of Oxford (reference: SOGE 1A2020-218). Refer to the Supplementary Methods for additional details of the survey instrument and results.

Of the actionable steps, "More effective academic-practitioner collaborations" was most ranked among the top three priorities (91% of respondents) followed by "Addressing social dimensions of effective restoration such as governance, land tenure issues" (72.7% of respondents) and "Addressing critical research gaps in the natural science side of restoration ecology" (54.5% of respondents) (Figure 1). Additionally, respondents said that actionable steps should "engage and collaborate with major corporate actors, especially transnational corporations whose activities have direct impacts on land use and land cover change" and highlighted the need for "more investments in restoration science, particularly for projects/individuals to continue to do long term research…", and the need for "…capacity building as an opportunity to co-develop actionable restoration knowledge…".

3 | YOUNG VISIONS FOR TROPICAL RESTORATION SCIENCE FOR THE UN DECADE ON ECOSYSTEM RESTORATION

We used the survey responses from the session participants (panelists and survey respondents) to inform our five visions for how young restoration scientists can actively contribute to developing restoration science over the UN Decade. Here, we outline these key visions and provide achievable contributions that young restoration scientists can make (Figure 2).

1. Vision 1- Tropical restoration science that includes strong and effective partnerships between science/academia, practitioners, private entities, indigenous people and local communities, and other stakeholders.

TABLE 1 Session called "Young voices in and visions for tropical restoration" was held on Thursday, July 22, 2021 as part of the Annual Association of Tropical Biology Conference 2021 (online)

Presentation title	Research region/ Study area	Highlights/Key findings of study presented	Vision proposed
A roadmap for tropical mountain restoration (Tina Christmann, University of Oxford)	Tropical Mountain Systems	• Due to diverse climatic niches and topography, tropical mountain systems consist of diverse ecosystems including montane forests in the lowlands, azonal formations, treelines, and high elevation grasslands. However, these systems are being degraded by different drivers of global change • Using a systematic review of 176 studies, the aim of the study was to understand how these systems are being restored • Tropical mountain restoration studies have sharply increased since 2010 and are mostly in Latin American montane forests. Many studies are short term and at patch or local spatial scales. Main motivation for restoration of these systems was for supporting ecosystem services such as forest and biodiversity recovery. Natural regeneration was the most studied technique (Christmann & Menor, 2021)	• More remote sensing and large-scale assessments of mountain restoration efforts • More studies about social dimensions of restoration and financial mechanisms encouraging mountain restoration • Use of technologies for site detection and monitoring • Inclusion of climate change implications in mountain restoration studies • More studies about restoration of alpine grasslands systems
Restoring connectivity in tropical forest systems: Benefits for biodiversity, climate, and key stakeholders (Rebekah Puttick, University of Newcastle)	Central Sarawak, Malaysian Borneo	• Deforestation and forest degradation including forest fragmentation are threats to forests globally. • Connectivity-based restoration techniques are being proposed to tackle forest degradation. • Connectivity can facilitate the movement of abiotic and biotic resources between patches in a landscape thereby enabling ecosystem functioning	• Emphasis of connectivity between people and nature that would then encourage increased impetus for restoration schemes in different ecosystems globally
Investigating the use of liana cutting as a tool for rainforest restoration (Emma Mackintosh, University of the Sunshine Coast)	Wet tropics of North Queensland, Australia	• Lianas, which are woody vines use trees for support to access the canopy and in turn causes mechanical stress and competition for resources. Most of the literature explores the negative effects of lianas including decreased tree growth and ability to store carbon and increased tree mortality. Lianas also have positive effects by providing food and movement pathways for invertebrates and protecting trees from strong winds and herbivory • The aim of this study is to understand if liana cutting is a solution or problem for rainforest restoration and if their role varies across tropical forests	• Future studies should focus on holistic restoration of ecosystems (not just tree growth and carbon sequestration, for example) • Emphasis on thorough research of different restoration techniques and their impacts on the ecosystem being restored

(Continues)

TABLE 1 (Continued)

Presentation title	Research region/ Study area	Highlights/Key findings of study presented	Vision proposed
Fine-scale assessment shows limited climate change mitigation potential of forest restoration in India (Trisha Gopalakrishna, University of Oxford)	India (country scale)	• Many countries have made ambitious pledges to increase forest areas to mitigate climate change. However, feasibility of these goals and locations to restore are debatable • Using India as a case study, and a wide variety of India specific spatial datasets, this study estimated the additional feasible area for natural regeneration to be 1.58 Mha cumulatively sequestering 61.2 TgC, which is substantially less than global estimates. • This study also highlights the additional area of 14.67 Mha for agroforestry delivering 98.1 TgC nationally. In the UN Decade on Ecosystem Restoration, the study recommends development of forest restoration strategies that are compatible with existing land uses like agroforestry (Gopalakrishna et al., 2022)	• More restoration studies in ecosystems and parts of the world that are currently underrepresented • More restoration science research that focuses on achieving diverse ecosystem and societal benefits and supports livelihoods • Future restoration science should assess the roles and impacts of diverse actors by gender, race, age group, and expertise • Future restoration science studies should focus on diverse methodologies, data, and resources when implementing and monitoring restoration schemes
Unraveling scale challenges in landscape restoration governance- evidence from Ecuador and Ethiopia (Daniel Wiegant, Wageningen University & Research)	Choco Andinom Pichincha and Bosque Seco, Loja Ecuador Mount Guna, Amhara, Ethiopia and Kafa Biosphere, Southern Ethiopia	• The aim of this study is to understand the challenges that emerge in the governance process on implementation of restoration efforts • Using semi-structured surveys and the lens of cross-scale and cross-level interaction between governance actors and natural regeneration efforts, the study estimates unrecognized actors and persistent mismatches across governance and ecological scales • Short-term government efforts did not match long-term restoration processes. Political cycles pushed for immediate success in the form of tree planting campaigns, with little focus on natural regeneration. There is a mismatch in federal budgets allocation for sustaining alternative livelihoods from restoration processes (Ecuador study- (Wiegant et al., 2020))	• Restoration science studies in the future should focus on understanding actual dynamics of implementing landscape restoration targets at subnational levels • Restoration science in the future should focus on current challenges in multilevel restoration governance, which will then offer opportunities to inform and improve ongoing and future restoration processes

TABLE 1 (Continued)

Presentation title	Research region/ Study area	Highlights/Key findings of study presented	Vision proposed
Now is the time to restore tropical agriculture (Michael Pashkevich, University of Cambridge)	Sumatra, Indonesia	• Restoration of tropical agricultural landscapes could provide large benefits including conservation of large remaining natural habitats and faster and more complete recovery after disturbance • As part of the Biodiversity and Ecosystem Function in Tropical Agriculture Program (BEFTA), the larger study includes testing how restoration affects the structural complexity, ecology, and productivity of oil palm systems • Key findings include that maintaining understorey vegetation can maintain or benefit the biodiversity of a large number of taxa and in turn the functioning they provide and that maintaining riparian buffers made of mature oil palms can benefit some arthropod groups after oil palm is replanted	• Increased investment of time, energy, and capital to address the "who," "where," "what" and "how" of restoring tropical agriculture • More experiments that test the efficacy of individual restoration strategies across spatial and temporal scales and identify low-cost restoration methodologies • Increased collaboration between stakeholders- academia, agricultural industries, and members of local communities to ensure that restoration benefits both human and natural systems

Note: The panel consisted of six doctoral students that presented their research and visions on a variety of topics and regions in the tropical biome about restoration science. The recording of the session has been made public at https://www.youtube.com/watch?v=6cuwGxZc128

Evidence-based partnerships, at every step, will inspire impactful research allowing achievement of the goals of ecosystem restoration (Brancalion & Chazdon, 2017; Holl & Brancalion, 2020). Partnerships should inherently and explicitly foreground the importance of co-producing knowledge, and consider a variety of world views, epistemologies, and cosmologies from various stakeholders (Di Sacco et al., 2021).

Contribution 1- Successful partnerships can be difficult to build and sustain by young researchers due to lack of know-how, time, and financial constraints. We recommend that young restoration researchers, local and foreign to the study area, identify all local stakeholders and include at least one main stakeholder with whom they can co-produce their research. Together, mapping the future of the partnership at the onset of their research and checking-in on progress and trajectory of the partnership will help in tracking, managing, and adjusting expectations. Alternatively, or additionally, local and foreign young restoration scientists could invest in capacity building activities such as mutual skill-sharing workshops and training and facilitating meetings on knowledge transfer between themselves and stakeholders. Local and foreign young restoration scientists should strive to encourage co-authorship and mutual mentorship between students from local and foreign universities. Lastly, young restoration scientists should aim to communicate research findings to as wide an audience as possible. For example, young restoration researchers can translate manuscript abstracts to languages used in the region of research, ensuring that local stakeholders are informed of the findings and implications. Local restoration science students could aim to translate their research to other local languages and English as translation of manuscripts could create a more inclusive scientific community, by making publications more accessible to all young restoration scientists. Doing so will strengthen the relationship between the young restoration scientist and the local stakeholder, leading to wider and longer-term impact.

2. Vision 2- Tropical restoration science that is conducted through a transdisciplinary lens.

Ecosystem restoration is an inherently complex endeavor and needs to be viewed through and practiced using cross-disciplinarity (i.e., view from different perspectives) and interdisciplinarity (i.e., requiring integration of knowledge and methods from different disciplines) (Keynejad et al., 2021). However, ecosystem restoration can be most effective when a transdisciplinary approach is taken, allowing for the limitations of traditional disciplines of ecology and environmental sciences to be overcome.

Contribution 2- Current young restoration scientists can contribute by developing ideas and designing transdisciplinary studies that include ecological, social, cultural, financial, policy and governance, and innovative technological aspects of tropical restoration science. We recognize that developing restoration projects while considering the multitude of facets can be time and resource intensive, making it difficult for young researchers who are often constrained by both time and budget. In such situations, we encourage effective collaborations between young researchers with a variety of expertise, making successful restoration more likely. A restoration science-focused network for young researchers, like the Early Career Scientist Committee of ATBC (ATBC, 2013) and

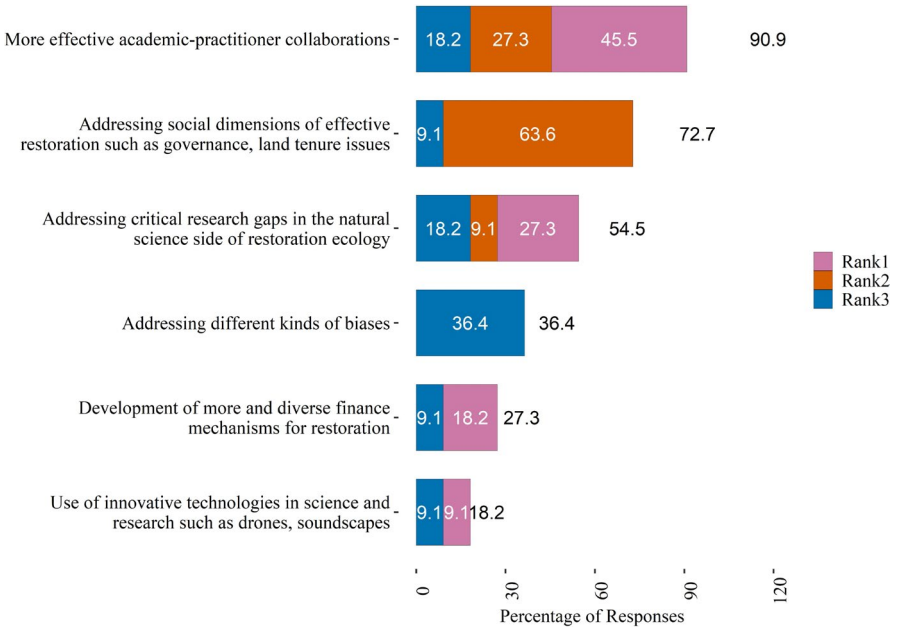

FIGURE 1 Distribution of top 3 ranked actionable steps for the UN Decade on Ecosystem Restoration. The number in the middle of each colored section of each bar refers to the percentage of total responses for the respective rank and actionable step and the number at the end of each bar is the percentage of respondents that chose the respective actionable step. Ranks are indicated by the three different colors. 11 survey respondents ranked the provided options in decreasing order of importance

student associations and resources from the Society for Ecological Restoration (https://www.ser.org) could help young researchers search for transdisciplinary collaborators. Existing initiatives such as the Environmental Leadership & Training Initiative (ELTI) and the Ibero-American and Caribbean Conference on Ecological Restoration (SIACRE) could initiate resources, networking, and training targeted specifically at the global young restoration science community. We also highlight the responsibility of faculty advisors, mentors, universities, and funders to encourage, support and reward transdisciplinary collaborations.

3. Vision 3- Tropical restoration science that represents different ecosystems in different parts of the world, using a variety of techniques.

Currently, restoration studies across the tropics are biased toward certain biomes and regions, and few occur across large spatial or temporal scales (Christmann & Menor, 2021). Findings from such studies are therefore site-specific and context-dependent, limiting the extent to which their findings apply to restoration initiatives more widely. Tropical restoration science in this decade should represent science across multiple ecosystems and geographies, including a variety of data gathering techniques (Dudley et al., 2020; Temperton et al., 2019).

Contribution 3- Tropical restoration science should include site-, plot-, and landscape-level research. This should also include measuring the effects of restoration across multiple ecosystems and geographic regions. However, when it is not possible to measure restoration at such large scales, young restoration researchers should use appropriate control and counterfactual set ups to ensure that single-site studies are most appropriately assessed (Cook-Patton et al., 2021; Reid et al., 2018). The findings of single system studies can be pooled with those from studies conducted by other young restoration scientists, facilitating landscape-scale restoration science research that sheds light on ecological interactions within different systems. Further, regional- and global-scale approaches could then identify global patterns and drivers of variability. For instance, young restoration scientists working with new restoration-focused databases, such as Restor (2021), can synthesize findings across individual restoration studies to better understand how restoration can provide benefits across space, time, and systems.

4. Vision 4- Long-term monitoring of restoration schemes using complementary field methods and innovative remote sensing technologies for multiple end goals.

Ecosystem restoration science should tackle disentangling and reconciling the contrasting outcomes of different ecosystem benefits and societal goals of livelihoods and well-being (Holl & Brancalion, 2020; Martin et al., 2021). In this vein, restoration projects must be monitored and evaluated after implementation and on long time scales (Poorter et al., 2021). Such long-term monitoring efforts are needed to assess achievement of multiple end goals decided at the inception of the project using participatory approaches that include the most vulnerable communities. We recommend using both established field-based monitoring methods and innovative and complementary remote sensing technologies. We recommend the use of remote sensing technologies include drone technology, LiDAR and multi/hyperspectral image sensors, soundscapes technologies, and camera traps that involve field data collection and field-based monitoring such as household surveys, interviews, and participatory workshops.

Contribution 4- Long-term monitoring and evaluation of ecosystem restoration programs can shed light on reasons for restoration success or, equally important, failures to meet the program goals (Cooke et al., 2019). Young restoration scientists can research how, when, and where different technologies can be used, and contribute

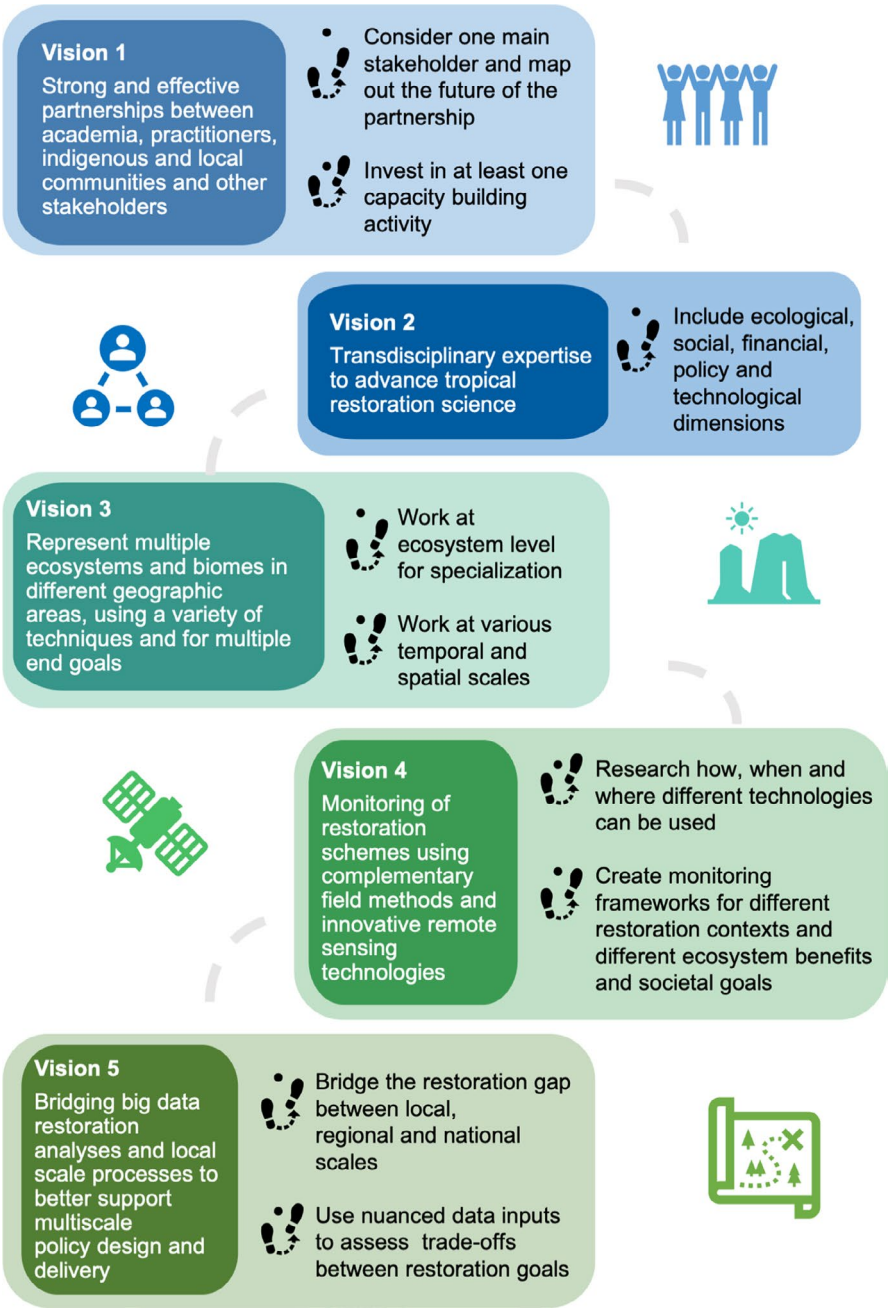

FIGURE 2 Five visions and respective action steps from and for the young restoration science community. The visions are in no order of importance

to developing a monitoring framework for different restoration techniques, goals/targets, and ecosystems. Such frameworks can be tried and tested by partnering with stakeholders, for instance, non-profit environmental organizations and private companies that are implementing restoration strategies or engaging with restoration projects. Lastly, these frameworks could then be incorporated into verification standards, certification schemes, and formulation of financial market instruments (for example, taxes and levies) that encourage accountability and support ecosystem restoration through technological advances.

5. Vision 5- Bridging big data analyses of restoration and local scale processes to better support multiscale policy design and delivery.

Big data restoration studies, including large-scale and long-term data, have provided the impetus for restoration action by showing the potential of restoration activities to achieve multiple goals at global and continental scales (Bastin et al., 2019; Brancalion et al., 2019; Griscom et al., 2017; Strassburg et al., 2020). However, these studies have many assumptions that vary by region and lack nuanced contextual information, potentially leading to ineffective or even harmful restoration outcomes (Holl & Brancalion, 2020). In the coming decade, fine-scale analyses should also be completed to support bottom-up policy design and delivery that will better support national and subnational policy making (Murcia et al., 2016).

Contribution 5- Global studies are often the basis for international campaigns, policies, and agreements, and also influence the development of restoration policy at the national and subnational

levels. Young restoration scientists can design studies that analyze the trade-offs between restoration goals, that can critique and refine global scientific assumptions, and that estimate uncertainty when accounting for contextual information, available at regional and subnational scales. In this manner, young restoration scientists can support effective policy design and delivery at the scales of implementation.

4 | CONCLUSION

There is a magnifying glass on the state of restoration (science, implementation, evaluation) in the current UN Decade on Ecosystem Restoration, with attention on successes, failures, and lessons to be shared. The current and future generations of restoration scientists will have to step up and lead the way, a challenge that will be as exciting as it is complex. Hence, supporting and increasing the participation of young voices in restoration science is vital to ensuring current and future successes within the field of restoration. Young restoration scientists can positively impact policy at multiple spatial scales by building transdisciplinary collaborations with local stakeholders, across ecosystems, regions, and goals/outcomes with implicit long-term monitoring and evaluation schemes. Proactive inclusion of these voices and, indeed, all restoration-focused voices, in the future restoration initiatives is critical to the development of this field as a science, and to ensuring that the impact of the UN Decade is beneficial and long-lasting.

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CONFLICT OF INTEREST

The authors declare no conflicting interests.

AUTHOR CONTRIBUTIONS

TG and TC conceived the idea for the session, wrote and submitted the proposal and organized and ran the session during the annual meeting of the Association for Tropical Biology and Conservation 2021 (with assistance from the Association for Tropical Biology and Conservation). TG, TC, MP, RP, and other panelists designed the survey. TG wrote various manuscript drafts with feedback and additional input from TC, MP, and RP. TC designed Figure 2 with additional input from TG.

DATA AVAILABILITY STATEMENT

The data that support the commentary are available from the Association of Tropical Biology and Conservation, as part of the annual meeting of the Association of Tropical Biology and Conservation 2021. Restrictions apply to the availability of these data, which were used with permission.

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