Research Topics

Engaging scientific diasporas for development: Policy and practices

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Engaging scientific diasporas for development: Policy and practices

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Editorial: Engaging scientific diasporas for development: Policy and practices

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Editorial on the Research Topic
Engaging scientific diasporas for development: Policy and practices

The study of scientific diasporas (SD) is more relevant than ever, and so is having a shift in the paradigm. The emigration of highly educated and science-skilled individuals from countries in the South to countries in the North has predominantly been understood as a loss of scientific knowledge and capabilities by the countries of origin for the benefit of the countries of destination. This has been known in the literature as "brain drain" and has remained a widely used paradigm for decades. However, a shift in such a conceptual framework has emerged, considering that such SD can turn into a valuable bridge between scientifically lagging and scientifically advanced nations.

Various countries are increasingly building connections between their national needs and interests with the capabilities of their SD. Such nations aim at strengthening linkages with their SD in the face of alliances for sustainable development. In addition, the SD from the Global South play an active role in the construction of academic networks and partnerships for transnational science projects. SD can support and enhance the quality of higher education in their home country, by bridging low levels of public and private investment through their capacities, learned technologies, and high-level training. On the other hand, the SD's identification, mapping, and characterization remain challenging for most developing regions of the world. Today's increasingly interconnected and globalized societies require the active circulation of knowledge and technology among nations. For this, it is necessary that policymakers, particularly those related to foreign service, generate effective and sustainable engagement initiatives with their SD. Various stakeholders are relevant, including universities, science academies, corporate firms, and international organizations.

This Research Topic came about as an attempt to address the limited literature on the highly qualified diaspora and their mobilization to different countries, as well as the lack of information on good practices and public policy strategies for engaging the SD.

This Research Topic, therefore, seeks to present not only empirical research conducted in various parts of the world but also to include representative cases and policy analysis. The papers published as part of this Research Topic show the plurality of edges the engagement of SD can entail and portray the multiple challenges faced by countries of origin to recognize, identify and map their SD as a critical first step to later engage with such SD for the development of their territories. These 14 papers are divided into three groups.

The first group of five papers seeks to contribute to the debate on the scientific diaspora and its potential to contribute to science diplomacy initiatives. The article "*Emerging Technologies, STI Diaspora and Science Diplomacy in India: Towards a New Approach*" (Pandey et al.) examines India's initiatives and strategies for engagement with the scientific diaspora. Using examples from other countries, this study outlines an approach with some examples of strategies and initiatives for harnessing science diplomacy to enhance engagement with the SD to create a win-win milieu for India and the diaspora. The paper "*Organized Scientific Diaspora and its Contributions to Science Diplomacy in Emerging Economies: The Case of Latin America and the Caribbean*" (Echeverria-King et al.) analyzes the interactions and initiatives identified between the organized scientific diaspora from Latin America and the Caribbean and their countries of origin concerning science diplomacy processes, providing recommendations and proposals for public policy to improve the interaction between the diaspora and the governments of their countries of origin. The opinion paper "*The Potential Contribution of the Scientific Diaspora to Enhance Marine Science in Guatemala*" (Barrios-Guzman and de la Cruz) is in line with the previous article, in the sense that it highlights the potential of the scientific diaspora and how it would contribute to the strengthening of science diplomacy. Based on a specific case study, the authors understand that academic and scientific actors outside the country could be a bridge for the execution of cooperation projects and activities, facilitating the exchange and transfer of knowledge and technology. Complementary to this, the paper "*Recognize and Alleviate a Resource Management Conundrum Facing Science Diaspora Networks*" (Butler et al.) contributes to the debate on science diaspora networks, understanding networked organizations and how they manage resources. The work provides a new database of operational science diaspora networks. The article "*Scientific Diasporas and the Advancement of Science Diplomacy: The InFEWS US-China Program in the Face of Confrontational 'America First' Diplomacy,*" (Prieto and Scott) presents a descriptive analysis of how science diplomacy played a critical role between the United States and China through the Innovations at the Nexus of Food, Energy, and Water Systems (InFEWS) US-China program, by promoting scientific collaborations to expand the food, energy and water nexus research and applications.

The second group composed of six papers, explored case studies of SD engagement in different countries, identifying and analyzing the peculiarities of each experience. The Guatemalan experience was studied in three papers. The paper "*Engaging the Guatemala Scientific Diaspora: The Power of Networking and Shared Learning*" (Bonilla et al.) outlines the Guatemalan scientific diasporas' (GSD) networking as a mechanism for building research excellence and intellectual capital. Findings highlight the importance of digital and technological pathways that might leverage the GSDs' knowledge and experience, channeling skills, and international connections for better interaction with Guatemalan society. Complementarily, the paper "*Connecting Scientists Residing Abroad: A Review of Converciencia as a Practice to Engage the Guatemalan Scientific Diaspora From 2005–2020*" (Bonilla, Arrechea et al.) analyzes the *Converciencia* program, designed to connect Guatemalan scientists residing abroad with their country of origin. This article presents a comprehensive and balanced overview of the program applying an in-depth analysis of its creation, evolution, leading trends, and legacies. The paper "*Developing a Digital Technology System to Address COVID-19 Health Needs in Guatemala: A Scientific Diaspora Case Study*" (Alvarado et al.) shows that SD are organized groups of professionals who can work together to contribute to their country of origin. Their collaboration was facilitated by FUNDEGUA, a Guatemalan non-profit, which provided a legal framework to establish partnerships and raise funds. The paper analyzed an initiative known as ALMA (*Asistente de Logística Médica Automatizada*), showing how SD can provide an avenue for professionals to contribute to Guatemala, regardless of their residence and job commitments. The Colombian experience outlined in the paper, "*Engaging Scientific Diasporas in STEAM Education: The Case of Science Clubs Colombia,*" (Avendano-Uribe et al.) showcases the Science Clubs Colombia (*Clubes de Ciencia Colombia*-SCC) program, a pioneering STEAM capacity-building initiative led by volunteer scientists to engage youth and children from underserved communities in science. The program brings together researchers based in Colombia and abroad to lead intensive project-based learning workshops for young students in urban and rural areas. In the Honduras experience, the paper, "*Engaging Honduran Science Diasporas for Development: Evidence from Three Consolidated Networks,*" (Bonilla, Valle et al.) portrays the dynamics of three consolidated diaspora networks, which provide evidence of their existence and engagement in their home country. Evidence showed that the Honduran SD are willing to transfer knowledge, build bridges, facilitate access to world-class research practices to their peers residing in Honduras while interacting with the broader sectors of the Honduran society. The Mexican experience is presented in the article "*Mexican Scientist Diaspora in North America: a perspective on collaborations with México*" (Gómez-Flores et al.) explored how the Mexican SD residing in North America are committed to aiding the country's development. However, a lack of institutional coordination has not harnessed their contribution to capacity building.

Finally, the last group of three articles delves into the relationship between indicators and the level of engagement of the SD. The article "*RAICEX: A Successful Story of the Spanish Scientific Diaspora*" (Ortega-Paino and Oliver) analyzed the role of the Network of Associations of Spanish Researchers and Scientists Abroad and surveyed the experiences of Spanish researchers distributed in several countries on five different continents. The main objectives of the program were to provide support to researchers and scientists in mobility and personal development, to disseminate and give visibility to the value of science and the work of researchers and scientists, promote communication of the advances of knowledge in all areas of society and promote international relations and cooperation. In the paper "*Biodiversity Research in Central America: A Regional Comparison in Scientific Production Using Bibliometrics and Democracy Indicators*," (Morales-Marroquin et al.) the aim was to show how the democratic shifts throughout the years have impacted the science production on biodiversity research and species records. The paper discusses democracy, science production, funding, and conservation as core elements that go hand in hand and that need to be nourished in a region that struggles with protecting life and extractive activities in a climate change scenario. Closing the collection, the article "*Voices of the Costa Rican Scientific Diaspora: Policy Lessons from a Decade of Experiences from our Scientists Abroad*" (Jarquin-Solis et al.) analyzes 10 years of diaspora perspectives as reflected by those interviewed. Authors extracted insights about the most common mechanisms and funding sources used by Costa Rican scientists seeking professional opportunities overseas, their level of engagement and collaboration with Costa Rican research and higher education institutions, and the possible incentives that the country could prioritize to harness their scientific talent and increase scientific capacities at home.

We, the co-editors, are convinced that these articles can contribute to future efforts and strategies for the engagement of SD from the Global South in the development processes of their country of origin. We believe that a major contribution of the Research Topic is the inclusion of different contexts and geographies. In addition, this Research Topic contributes to increasing the visibility of the engagement of SD for development, allowing for counterbalance on the emphasis, focus, and narratives that have dominated the literature. We look forward to seeing a growing interest in studying and understanding the dynamics of SD from the perspective of their countries of origin. We thank all the authors, co-authors, reviewers, and external editors who participated in this process. We also thank Frontiers in Research Metrics and Analytics for making it possible to publish this Research Topic and all the articles as part of this collection.

Author contributions

KB: conceptualization (lead), structure (lead), methodology (lead), resources (lead), validation (lead), and writing—original draft (lead). LE-K and MS: conceptualization (equal) and writing (equal). TM: copyediting (lead). DB: contribution of ideas (assisting). All authors contributed to the article and approved the submitted version.

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Organized Scientific Diaspora and Its Contributions to Science Diplomacy in Emerging Economies: The Case of Latin America and the Caribbean

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The current knowledge society has driven an unprecedented mobility of people, especially scientists, from emerging economies to developed countries. This mobility can allow the development of human talent and the access to first class infrastructure and resources, but it can also mean a loss for emerging economies due to the phenomenon of brain drain. To counteract this situation, some countries in Latin America and the Caribbean have developed models for the articulation of their scientific diaspora in projects and programs, with the aim of exchanging knowledge and capitalizing on human and technical resources to advance science, technology and innovation systems. Likewise, science diplomacy has become a tool for interlinking the work of various actors in order to advance the solution of national, transnational or global problems through scientific advice. Scientific diasporas are vital in new structures of cooperation, enabling them to innovate and solve problems jointly, advising their countries of origin and articulating policies and programs. This research seeks to analyze the interactions and initiatives identified between the organized scientific diaspora from Latin America and the Caribbean and their countries of origin in relation to science diplomacy processes, providing recommendations and proposals for public policy to improve the interaction between the diaspora and the governments of their countries of origin. Results show that diaspora organizations from Latin America and the Caribbean engage with governmental and non-state actors and are active science diplomacy stakeholders promoting the scientific developments of their country or their researchers, as well as enabling access to research resources creating alliances for scientific, institutional and academic collaborations. In the cases studied, these efforts are planned and executed by the diaspora without responding to any science diplomacy strategy of the country. Policies and programs are needed to effectively link the scientific diaspora organizations to the interests of the countries.

Keywords: scientific diaspora, science diplomacy, emerging economies, research policy, Latin America, diaspora networks, international cooperation

INTRODUCTION

The concept of diaspora comes from the ancient Greek and refers to dispersing seeds (Plaza, 2013); currently it refers to the relocation of a group of people from their place of origin to a new country, creating a connection not only with their homeland, but also with the host country. Diasporas also have a group consciousness, creating their own identity in relation to their country of origin and members of other regions or communities (Fernández, 2008). Diasporas build bridges between societies and create mutually beneficial transnational communities in terms of development for host and home countries. Strategic partnerships between States, international organizations, civil society, and industry provide a framework for diaspora engagement and empowerment by sharing and transferring their resources. The role of diasporas in the human, social, and economic development of countries, poverty reduction, reconstruction and growth is gaining considerable interest globally. Integrating diasporas into local development projects that represent a real added value for national economies is at the heart of migration management, as it establishes effective cooperation between countries of origin and destination to support their diasporas in contributing to development (IOM, 2007).

The mobility of highly-qualified workers from emerging economies to developed countries can foster human talent and access to first class infrastructure and resources, but it can also mean a loss for emerging economies due to the phenomenon of brain drain. However, the expatriate skilled population can be also considered as a potential asset instead of a loss. In particular, when referring to scientists and engineers abroad. If the countries of origin can use the scientific diaspora as a resource then the gains can be substantial. Science diplomacy (SD) strategies in developing countries often aim to articulate the scientific diaspora to capitalize on the human and technical resources, and advance national science, technology and innovation (STI) systems, which enables the paradigm shift toward the circulation of knowledge. Through a quantitative survey to 10 diaspora organizations and three qualitative focal group studies, we unveil how the organized scientific diaspora from Latin America and the Caribbean (LAC) currently understands and contributes to SD processes. Based on these results we propose public policy recommendations to improve the interaction between the diaspora and the governments of their countries of origin.

This article is organized as follows: first, conceptual approaches regarding the scientific diaspora and SD will be introduced. Next, the situation of the Latin American and Caribbean scientific diaspora will be addressed, including some examples of programs intended to engage the scientific diaspora with their countries of origin. The methodology of the study will then be presented and both quantitative and qualitative results will subsequently be reported. The discussion section will be followed by recommendations for scientific diaspora organizations and governments and public policy implications. The article ends with a section of conclusions.

SCIENTIFIC DIASPORA: CONCEPTUAL APPROACHES

There are different types of diaspora, which respond to different reasons for displacement. Within the framework of the current knowledge society, global competition for talent has increased dramatically, causing the mobilization of professionals in search of a better future, especially from emerging economies to industrialized countries. The International Organization for Migration Migration Policy Institute (2012), highlight the importance of creating an enabling environment for diaspora engagement through the creation of "diaspora and development" programs and the implementation of a commensurate regulatory framework that promotes benefits and obligations focused on a highly mobile population. This article will focus on the diaspora that migrates for scientific purposes: to advance their scientific career or to work in sectors requiring specialized, scientific skills. Gëdeshi and King (2019) describe as scientific diaspora a country's scientific talent moved abroad, including those who obtain high level training abroad. From a transnational approach, the scientific diaspora refers to highly qualified migrants who not only acquire knowledge in the host country, but also contribute to their homeland, becoming agents of development facilitating knowledge, connections and technology transfer (Tejada, 2007). For the purposes of this research, we will use this transnational approach of the scientific diaspora to understand the possible connection between this phenomenon and SD processes.

According to Shin and Moon (2018) there are three approaches to the migration of high-skilled nationals or what the authors refer to as the approaches to *brain power*: First, the *brain drain* approach, which refers to the negative impact of migration in the scientific landscape of a country and the loss of talent that results from emigration. In traditional schemes, the diaspora has been considered a *brain drain* for developing countries. Second, the *brain circulation* approach, common in less developed countries, recognizes a potential positive impact of migration only when migration is followed by the return to the home country. And third, the *brain linkage* approach, which refers to the power of the home-host interactions in which emigrants decide to engage, even when they do not return to their home country. There are a number of determinants that may support or hinder the effectiveness of a *brain linkage* approach, such as information about institutional initiatives, a stable political landscape and adequate STI infrastructure in the home country (Tejada et al., 2013).

Policymakers and public policy play an important role in enabling and fostering cooperation and engagement of the scientific diaspora with their countries of origin. According to Martinez Pizzaro (2005), the brain drain is a problem that should be addressed through public policy schemes for the following reasons: (i) The scarce initiatives to encourage the return of qualified emigrants prevent the internalization of strategies in the field of STI, and the benefit of their valuable experiences; (ii) The existing networks have been sporadic, and have not had sustained governmental support over time, despite having been conceived as unique meeting spaces between scientific diasporas and local communities; (iii) The organized diaspora finds acceptance among well-organized migrant communities, but it is not directly embraced in the context of STI.

Scientific diaspora may become organized through diaspora networks. These networks refer to a map of actors where diaspora participates with key actors both in the home and host country, such as universities, companies, research centers, international cooperation agencies, among others. Organized scientific diaspora networks facilitate the interaction and knowledge transfer between the country of origin and the host country. These networks emerged due to the interest of individuals abroad to gather and take advantage of a shared identity and culture, to contribute to their home country and sometimes thanks to explicit national policies and programs that promote linkages with the scientific diaspora.

The digital era has supported the consolidation of these scientific diaspora networks, establishing meaningful virtual connections with various stakeholders in their home and host countries to advance joint projects and activities (Grossman, 2010), in particular for the development of STI. Organized scientific diaspora networks may boost innovation by supporting and building commercial bridges, facilitating access to products and services developed abroad and enabling value-generating investments without having to return home (Epstein and Heizler, 2016). Thus, from a transnational and brain linkage approach, scientific diaspora becomes a key actor for science and innovation diplomacy schemes (Echeverría King et al, 2021), especially for emerging economies like those in LAC with a large population of expatriates not intending to return to their home countries.

SCIENCE DIPLOMACY

SD is experiencing a time of excitement in LAC. Initiatives on SD across this region tend to grow on a sound basis (Gual, 2020). In spite of that, the concept of SD remains widely unknown in LAC. This is mainly because the term SD is relatively new. Even though the interactions between researchers and diplomats date from long ago, this concept received its first taxonomy in 2010, to encompass the intersection between the actions on Science, Technology and Innovation, and those of the international community (The Royal Society, 2010).

The wider literature defining this concept confirms that there is no such thing as a one-size-fits-all SD approach (Rungius et al., 2018). Since 2010, many efforts have attempted to provide a definition of SD. According to Turekian (2018) SD supports the development of science and knowledge exchanges that go beyond the generation of scientific achievements. Epping (2020) explains that SD considers science to be a vehicle to foreign policy goals by addressing the pre-political room in the sense of operating as a depoliticizing element and unfolding impact in different ways than traditional diplomacy.

Although this region has no common definition for SD, three specific dimensions are identified in most of these countries, which help shed some light about how this concept is understood in LAC. For this purpose, the "strategic purposes approach" from Flink and Schreiterer (2010) distinguishes three types of actions undertaken by State stakeholders to enact SD. First, "Access" refers to actions aiming to support the competitiveness of a national STI ecosystem at global scale. Second, "Promotion" seeks to improve the reputation and attractiveness of a country by highlighting its performance on STI. Third, "Influence" includes the actions of a nation designed to engage the foreign policy-makers and the public opinion by taking STI as an entry point.

A more utilitarian approach than the one here above sorts out the actions on SD into three categories. First, the actions to advance a country's national needs; second, the actions to address cross-border interests; and third, the actions primarily designed to meet global needs and challenges (Gluckman et al., 2017).

SD in emerging economies can have different approaches and facets. It can serve for capacity building, development of human talent and fostering of knowledge and technology transfer (Arunachalam et al., 2017). Also, SD has supported emerging economies to establish meaningful partnerships to work toward the Sustainable Development Goals of the 2030 Agenda (Thompson, 2018; Echeverría et al., 2020). It also fosters the search for solutions to regional or transnational health challenges (Jarquin-Solis and Mauduit, 2021), as seen during the Covid-19 pandemic. The alliances promoted by SD have helped to leverage South-South relations, such as between Brazil, Russia, India, China and South Africa (the BRICS countries); sharing resources and infrastructure in order to solve common problems (Bonilla et al., 2021). Through the exchange of experts and the installation of capacities in emerging countries, SD also facilitates a balance of power and alleviates asymmetries between the North and the Global South (Hornsby and Parshotam, 2018), reducing bad practices such as neo colonialism in international relations and science cooperation. SD also promotes the development of resources and conditions for the return of the scientific diaspora to the country of origin (IOM, 2007).

THE SCIENTIFIC DIASPORA AND SCIENCE DIPLOMACY IN LATIN AMERICA AND THE CARIBBEAN

As Latin American governments established national STI systems (Organización Internacional para las Migraciones, 2007), the need for human capital strengthening policies became apparent. This scenario has created better conditions for the skilled diaspora to be considered an important actor within the innovation and scientific development system. In this sense, several Latin American governments are making efforts to encourage the return of skilled migrants or to contribute to networks between professionals and scientists living abroad and those in the country.

In **Table 1**, we present different public initiatives from LAC that demonstrate the increasing recognition of the scientific diaspora as a local human resource through the development of policies and programs focused on generating spaces for exchange or stimuli for return. For example, Colombia had a particular case with the linkage of the organized scientific diaspora through the Caldas Network that ended between 2000 and 2002. With COLCIENCIAS as coordinator, the network

TABLE 1 | Examples of programs, laws or public policies regarding the highly qualified diaspora in Latin America and the Caribbean from 1990 to 2021.

Country	Program/law/public policy	Year	Description	References
Argentina	Crear – Revinculación de científicos, técnicos y profesionales Argentinos	1999-?	Promote communication between scientists abroad and the local scientific community.	Tigau, 2010
	Programa Nacional para la Vinculación con Científicos y Técnicos Argentinos en el Exterior (PROCITEXT)	1990-1999	Coordinate institutional efforts, design initiatives to benefit from the capacity of emigrated researchers, facilitate the return of emigrated researchers who wish to return, and promote linkages with those who remain abroad."	Lujan Leiva, 2005
	Raíces (Red de Argentinos/as Investigadores/as y Científicos/as en el Exterior)	2003-present	Promote the return, develop linkage policies, promote participation in the construction of the national science, technology and innovation policy of Argentine researchers living abroad. Promote international training and development opportunities for scientists that can be incorporated in the country.	Ministerio de Ciencia Tecnología e Innovación, 2021
Brazil	Actions to Benefit Brazilians Abroad' Action Plan	2011-2012	Organize activities with the diaspora on consular services, politics, education, social security, labor, culture, communication, economy, science and technology.	Ministério das Relações Exteriores, 2017
Caribbean	Tratado de Chaguaramas (revisado)	2001	Allow free movement of CARICOM members through the region.	Comunidad y Mercado Común del Caribe, 1973
	CARICOM-Caribbean Conference on the Diaspora: A 2020 Vision	2007	Identify how to create close links with the diaspora, its resources and knowledge to the advantage of the region.	Minto-Coy, 2009
Chile	DICOEX	2000- present	Promote the inclusion of Chileans abroad in the country's activities, defend their human rights, strengthen their ties and identity with Chile, encourage network formation to promote Chilean talents, train community leaders, inform on public policies that may concern them, study international migration issues, propose the components of the migration agenda and coordinate the participation of the Foreign Ministry in international forums on migration.	Ministerio de Relaciones Exteriores de Chile (MRREE), 2021
Colombia	Colombia Nos Une	2003 - present	Link Colombians abroad and make them subjects of public policies, strengthen the community abroad, accompany the return to the country, identify and establish contact with distinguished expatriates, offer services and benefits that contribute to raising the quality of life of Colombians abroad. According to law 2136, facilitate the execution of cooperation projects of the national diaspora with business, cultural, academic and research projects.	Cancillería de Colombia, 2022a
	Plan de Retorno Positivo	2009- 2011	Support the return of nationals abroad with economic and social opportunities that contribute to the country's development.	Cancillería de Colombia, 2022b
	Es tiempo de volver	2014	Incorporate Colombian doctors residing abroad through postdoctoral fellowships in universities, research centers, technological development centers and companies.	Ministerio de Ciencia y Tecnología de Colombia, 2014
	Ley 1565 del 31 de julio de 2012	2012 - present	Create financial incentives to promote the return of Colombians, and provide support to those Colombians who voluntarily wish to return to the country.	Cancillería de Colombia, 2022c

(Continued)

TABLE 1 | Continued

Country	Program/law/Public policy	Year	Description	References
	Red Caldas	1991-2002	"Integrate Colombian researchers abroad to the national scientific community and to the activities of the National Science and Technology System."	Chaparro et al., 2004
	Ley 2136 de 2021	2021	Diaspora integration policies. Promotion of diaspora networks through international cooperation mechanisms to improve the quality of research. Guide for Colombia Nos Une	Congreso de la República Colombiana, 2021
Ecuador	Programa Prometeo	2011-2017	Strengthen the country's academic and research capacity by incorporating outstanding scientists, and Ecuadorians living abroad, into the Ecuadorian academy and research centers.	Chiriboga Salazar, 2019
	"Ecuador Saludable, Vuelvo por ti"	2012	Recruit Ecuadorian and foreign health professionals abroad, prioritizing highly trained specialists and sub-specialists to cover the requirements in critical areas and undersupplied regions of Ecuador.	Ministerio de Salud Pública, 2022a,b
	Plan Retorno Educación	2013-?	Recruit professionals in education or other areas from Ecuadorians living abroad.	Ministerio de Educación Ecuador, 2022
Mexico	Red Global MX	2005 - present	Organizes highly qualified Mexicans who live outside the country and are interested in promoting the development and good image of Mexico.	Instituto de los Mexicanos en el Exterior, 2018
Panama	Programa de repatriación de talento	2006-?	Repatriation of internationally recognized Panamanian scientists.	Aguilar, 2022; SENACYT, 2012
Peru	Ley del Retorno (Ley N° 30001)	2013-2016	Facilitate the economic and social reintegration of Peruvian migrants and their families, including the recognition of studies carried out abroad, access to social programs and subsidies. Regarding skilled migration, support from the National Council for Science, Technology and Technological Innovation (Concytec) to scientists and researchers who take advantage of it.	Congreso de la República Peruana, 2013; CONCYTEC, 2020
	Encuentro Cientifico Internacional	1993 - present	Exchange experiences and knowledge, establish cooperative relationships between research centers and institutions in Peru and abroad.	Gual, 2020; ECI, 2022
Suriname	Diaspora Institute Suriname	2017	Organize and structure cooperation with the diaspora worldwide to connect as many diaspora as possible with local projects, people and initiatives.	Diaspora Instituut Suriname, 2022
Uruguay	Programa de Vinculación con Uruguayos Altamente Calificados residentes en el Exterior	2001-2005	Support Uruguayan professionals abroad as qualified human resources for collaboration and contribution to the country's development.	Presidencia de la República Oriental del Uruguay and Secretaría de Prensa y Difusión, 2001
	Departamento 20 (Dirección de Servicios Consulares y de Vinculación con los Uruguayos en el Exterior)	2005- present	Form Advisory Councils in countries with a higher concentration of emigrants and diplomatic representation, create a voluntary consular registry of emigrants and increase the efficiency of the Foreign Service.	Taks, 2006
	Programa de Circulación de Uruguayos Altamente Calificados (CUAC)	2005- present	Link highly qualified Uruguayans living abroad with the country's institutions through this network of academics, business persons, artists and cultural agents.	Ministerio de Relaciones Exteriores de Chile (MRREE), 2021
Venezuela	Talento Venezolano (TALVEN)	1994-?	Link Venezuelans residing abroad, who have studied with the financial support of the State, to their peers in Venezuela, and sponsor the return of Venezuelan scientists to teach in local institutions.	Guellec and Cervantes, 2002

linked student and professional associations abroad, which facilitated the start of the network and proved to be one of its success factors (Chaparro et al., 2004). For its part, the Chilean government created DICOEX in 2000, whose objective is to strengthen relations with Chilean professionals living abroad and to promote cooperation and knowledge transfer between them and the country (IOM, 2007). DICOEX has a database of Chilean organizations abroad that are easily accessible through its website, helps fund existing associations abroad, and provides information to expatriates (Ministerio de Relaciones Exteriores de Chile (MRREE), 2021).

In the case of Argentina, it has a long history of skilled migration. The governmental program "Argentine Network of Researchers and Scientists Abroad" (MINCYT, RAICES, 2021), created by Law N° 26.421, is under the Ministry of Science and Technology (Secretariat of Planning and Policies in Science, Technology, and Innovation). The initiative develops strategies to strengthen the country's scientific and technological capacities through links with the scientific diaspora helping them to create networks and with the local STI system.

In Uruguay, the "Programme for the Circulation of Highly Qualified Uruguayans (CUAC)" has been in place for several years. The Advisory Councils and the "Department 20" within the orbit of the General Directorate of Consular Affairs and Liaison of the Ministry of Foreign Affairs, currently focuses on the term "diaspora of Uruguayans abroad" (although the decree creating Department 20 is still in force). In 2018, an important pilot experience called "active citizenship for development" was carried out. The meeting brought together members of the diaspora interested in contributing their knowledge to Uruguay and deepening their relationship with the country at the scientific, technological, and business levels; with priority in the areas of biotechnology and pharmaceuticals, information technologies, energy, food, forestry, and the country's scientific and technological development (Uruguay Presidencia, 2018).

The integration between highly qualified diaspora networks across Latin America has also been explored more recently. The research and development program "Creation of incubators of knowledge diasporas for Latin America" (CIDESAL), financed by the European Union, sought to establish links and public policies for cooperation with professionals living abroad (Meyer, 2015). The initiative involved the French Institute of Research for Development (IRD), the Centro Redes of Argentina, Colombia Nos Une of Colombia, the Faculty of Social Sciences of the University of the Republic of Uruguay and the Polo Mercosur Foundation.

In addition, the European Union Global Diaspora Facility (Diaspora for Development, 2021) pilot project is an initiative implemented by the International Center for Migration Policy Development (ICMPD) that seeks to consolidate efforts on diaspora engagement in development by encouraging participation and creating a laboratory of innovative ideas and policies, based on needs and priorities. The European Union Global Diaspora Facility created the Diaspora Engagement Map using data from the United Nations (UN) and the World Bank. This map allows the visualization of the Latin American diaspora by country, providing graphs, information on policies and institutions, as well as information on the various projects involving diasporas in each area.

Despite the initiatives mentioned in **Table 1** and discussed in the text, diaspora integration policies in LAC are isolated and independent events, of short duration, and where the different actors of society that could benefit from the diaspora are not integrated. There is predominantly unidirectional communication from the government to the diaspora, with few institutional spaces to take into account the experiences of the diaspora in the design of public policies on science and technology. Additionally, a large part of public policies are oriented toward individuals and not necessarily toward the organized diaspora (López-Vergés et al., 2021). In addition, science still plays a secondary role in the foreign policy agenda of the region. This is why Latin American governments are proposing the generation of SD schemes based on the knowledge and experience acquired by the organized diasporas. For example, Colombia is currently developing its SD strategy to include a better articulation of the scientific diaspora (Gual, 2020). To generate synergies in the aforementioned context, it is advisable for national scientists to articulate with networks of scientists abroad promoting "brain linkage." The greatest challenge is to achieve this interdisciplinary and trans disciplinary linkage between actors and policies of science and diplomacy (Gual, 2020).

Today's globalized society is supported by a State that promotes public policies and an international bureaucracy that is emerging as the new instance of power. The globalized society is immersed in a world where all individuals can communicate and cooperate, whether they are in the West, in the East, in the North or in the South (Gómez Lee, 2008). The optimal situation to promote exchange with the diaspora in today's society is for governments to create conditions conducive to their existence, facilitating cooperation and access to dialogue. The role of facilitator is itself a form of network, with the government being the one who would be drawn into engagement with the diaspora, fostering capacity building, and mutual understanding (Aikins and White, 2011). From this perspective, it is necessary for Latin American governments to work on policies that integrate SD schemes and cooperation with the diasporas. Policies that are not only isolated events but become true SD strategies in the country's foreign policy.

METHODS

General Objective of the Study

To analyze the interactions and initiatives identified between the organized scientific diaspora and the governments of their countries of origin in relation to SD processes, based on an initial review of existing organized (scientific) diaspora networks in the region, as well as on three representative cases from LAC, in order to provide recommendations and proposals for public policy to improve the interaction between the diaspora and their countries of origin.

Design and Procedure

The present study is descriptive and exploratory. It follows a mixed research design. The main use of mixed methods in research is to strengthen the validity of the studies and the consistency of the resulting conclusions (Schoonenboom and Johnson, 2017). In addition, the combination of quantitative and qualitative methodologies contributes to a broader understanding of complex research problems (Creswell, 2009).

In the first part of the study, a survey was distributed to Latin American diaspora organizations in order to identify which of these groups were engaged in SD activities. In the second part, three Latin American scientific diaspora organizations were identified using as criteria their engagement in SD activities and their willingness and availability to participate in this study. These three diaspora groups participated in focus groups to understand their interactions with their home countries in SD activities.

Data collection was carried out between June and October 2021.

Participants

Selection of Latin American and Caribbean Scientific Diaspora Organizations

The authors identified 27 Latin American and Caribbean scientific diaspora organizations based mostly in Europe and North America through online searching and the network's contact information. Organizations from individual or multiple countries were considered. All organizations selected had their own website or an official government page (save for Red de Uruguayos Universitarios en Finlandia-URUFI-) to ensure the organizations had a certain level of maturity. The scientific diaspora organizations selected also needed to be active and to have a highly-qualified focus or field. An attempt was made to include organizations across the region.

A quantitative questionnaire was created to determine the objectives of the selected diaspora organizations, and to identify SD projects, initiatives and interactions undertaken by these organizations. The questionnaire was divided into three sections: (i) sociodemographic analysis, (ii) objectives of the organization, (iii) characterization of SD activities.

Table 2 contains the 27 organizations identified and approached to complete the quantitative questionnaire. Among these, only 10 answered. Based on their responses, three were selected for a qualitative study through focus groups. The criteria for selection to the qualitative study included at least three of the following: (1) multidisciplinary focus, (2) engagement with homeland institutions, (3) residence of all members outside of their home country, (4) structured organization, (5) SD activities, (6) representation of different Latin American and Caribbean subregions.

It was not possible to know how many members partake in each one of the 27 organizations. Only the three interviewed organizations provided that information. The 10 organizations that filled in the questionnaire are a good representation of the reality of the study population as they include most of the subregions within LAC.

Diaspora Organizations Participating in Focus Groups

Considering the criteria of willingness, availability and the organization of SD activities, the diaspora organizations URUFI, INVECA, and CEVALE2VE were chosen to participate in this study. INVECA has 120 members, 30 of them were active at the moment of conducting this research. URUFI has 22 members whilst CEVALE2VE has 20 active members. A focus group was conducted with each organization. Each focus group lasted approximately one and a half hours. The Interview Guide for the focus groups contained questions related to general information about the diaspora organization, the interviewees' conception of SD, the activities carried out by the diaspora with the governments of their countries of origin, and recommendations for improving the interaction between the diaspora and the governments of their country of origin. The persons interviewed at each session of the focus groups were either members of the board of directors or other leading members of the organizations, corresponding to four persons in the case of CEVALE2VE, three participants in the focus group of INVECA and two persons in the case of URUFI.

The following is a brief description of each of the diaspora organizations, their date of creation and the number of active members to date.

INVECA

The Network of Chilean Researchers in Germany (Red INVECA e.V.) started its activities in 2012. Since then, the network has brought together more than 120 Chilean researchers from different disciplines living in Germany to discuss academic issues, science policies and aspects related to the development of science, based on their own experiences. To generate these spaces for dialogue, several annual conferences have been held (Berlin, 2012; Heidelberg, 2013; Bamberg, 2014; Frankfurt, 2015; Berlin, 2016; Hamburg, 2017; Karlsruhe, 2018; Freiberg, 2019) that have allowed strengthening relationships with academic and scientific organizations in Chile and Germany, including official entities of both countries. Currently 30 members have active membership. Since 2015 the network has had legal status (RedINVECA, 2021).

URUFI

The Network of Uruguayan Academics in Finland (URUFI, by its Spanish acronym) started running regular meetings with its members in November 2016. It currently has 22 members with different profiles, some dedicated to the academic and scientific field and others to the business field. URUFI's mission is to be a tool for the linkage and mutual cooperation between Uruguayans in academic and specialized diaspora residing in Finland, in order to facilitate the creation of professional links and promote initiatives that stimulate the creation of joint projects (UYREDES, 2021).

CEVALE2VE

Centro Virtual de Altos Estudios de Altas Energías (CEVALE2VE) is an initiative of the Venezuelan scientific diaspora to strengthen academic training, networking, research and outreach in the area of High Energy Physics (HEP). Initially

TABLE 2 | List of Latin American and Caribbean scientific diaspora organizations contacted.

Name of organization	Country(ies) of origin	Region/Country of residence	Website
Red de Investigadores Chilenos en Alemania (INVECA)	CL	DE	redinveca.cl
Investigadores Chilenos en Suiza (ICES)	CL	CH	ices-net.ch
Red de Investigadores Chilenos en Países Bajos (IN.NL)	CL	NL	in-nl.net
Nexos	CL	USA	nexoschileusa.org
Red de Investigación Chile-Canadá (REDICEC)	CL	CAN	redicec.com
UQCHILE	CL	QUEENSLAND, AUS	uqchile.com
Red de Investigadores Chilenos en España (Red INCHE)	CL	ES	twitter.com/redinche
Red de Científicas/os Argentinos en Alemania (RCAA)	AR	DE	rcae.info/category/alemania
Red de Científicas/os Argentinas/os en Israel	AR	IL	argentina.gob.ar/ciencia/raices/redes-exterior/israel
Red de Científicas/os Argentinas/os en Italia	AR	IT	rcai.it
Red de Científicas/os Argentinas/os en Países Bajos	AR	NL	sites.google.com/view/rcapb/inicio?authuser=1
Red de Científicas/os Argentinas/os en Reino Unido	AR	UK	argentina.gob.ar/ciencia/raices/redes-exterior/reino-unido
Red de Científicas/os Argentinas/os en Suiza	AR	CH	argentina.gob.ar/redes-de-cientificasos-argentinasos-en-el-exterior/en-suiza
Diáspora Brasileira de Ciência e Inovação na Alemanha	BR	DE	diaspora-ctibr.de
Fundación México-Estados Unidos para la Ciencia (FUMEC)	MX	USA	fumec.org
Centro Virtual de Altos Estudios de Altas Energias (CEVALE2VE)	VE, CO, PE, MX	Global	cevale2ve.org/es/inicio/
Diáspora Científica por Venezuela	VE	Global	sites.google.com/view/diplomaciacientificave
HIPATIA	CR	Global	hipatia.cr/dashboard/diaspora-cientifica
Caribbean Diaspora for Science Technology and Innovation-New England	Caribbean	NE-USA	cadsti-ne.org
Caribbean Diaspora for Science, Technology and Innovation (UK)	Caribbean	UK	cadsti.org.uk
Caribbean Diaspora for Science Technology and Innovation-Silicon Valley	Caribbean	SValley-USA	cadsti.org/cadsti-sv
Asociación Colombiana de Investigadores en Suiza (ACIS)	COL	CH	acis.ch
Asociación de Científicos Peruanos, Cientificos.pe	PE	Global	Cientificos.pe
Sinapsis	PE	Europa	sinapsis-peru.org
Research Experience for Peruvian Undergraduates	PE	USA	repuprogram.org
Universidad Simon Bolivar Alumni Association of America (USB alumni)	VE	Global	alumnusb.org/about-our-work
Red de Uruguayos Universitarios en Finlandia (URUFI)	UY	FI	uyredesuyredes.wordpress.com/redesuy-finlandia

created to reach the Venezuelan academic community, it has now expanded to several Latin American countries. Activities began in 2014. Currently the activities of the network are mainly focused on the Latin American Alliance for Capacity Building in Advanced Physics (LA-CoNGA)[1], a capacity building project in advanced physics co-funded by the ERASMUS+ program of the European Commission. LA-CoNGA physics has designed and developed an educational program within the framework of a Latin American Alliance in Advanced Physics for students in Colombia, Ecuador, Peru, and Venezuela. At present this organization has approximately 20 active members (CEVALE2VE, 2021).

Data Analysis

For the analysis of the data obtained from the focus groups, the qualitative content analysis method (Mayring, 2000) was applied. MAXQDA software[2] was used to facilitate the inductive organization of categories. The following categories were created:

- Network features
- Conceptions of science diplomacy
- Engagement initiatives of the diaspora with their governments
- Recommendations for diaspora-government linkages

This was followed by the research report, which included quotations from the focus groups conducted.

[1] https://laconga.redclara.net/

[2] https://es.maxqda.com/

RESULTS

Quantitative Results

The diaspora organizations that answered the quantitative survey were mostly established in European and North American countries and originated from countries across South America and the Caribbean (**Figure 1A** and **Table 2**). Unfortunately, no diaspora organization from Central America participated in the survey. Most of the surveys were answered by the presidents or members of the governing boards of the organizations (80%), the majority of whom held a PhD (90%), and were working in either academia (70%) or the private sector (30%). Consistent with our focus on well-established organizations, 80% of organizations declared having legal representation (**Figure 1B**) and at least 50% had applied to calls for proposals or projects in their country of origin or country of residence (**Figure 1D**). The highly-qualified and scientific nature of these organizations was also evident in their objectives, which were mostly focused on educational and scientific goals, with other goals like connecting immigrants and organizing social events showing less prevalence (**Figure 1C**).

To understand the interactions and influence of these diaspora organizations, we sought to determine the types of past activities or relationships undertaken with government and other non-state actors. Seventy percent of the organizations reported receiving support from the government of the country of origin and 60% from the government of the country of residence (**Figure 1D**). In the case of the country of origin, this help was presented in the form of financial support, competitive funds or in-kind support for activities; use of embassy premises; support for event promotion; scholarships for students and participation of public institutions in events. Only embassies or foreign affairs offices were mentioned specifically as providers of support. In the case of the country of residence, support was reported in the form of financial support for events and projects (including projects in the country of origin), participation of public institutions in events and support for event promotion. The ministry of science, institutions for the integration of migrants, institutions that promote cooperation with Latin America and public universities were mentioned specifically as having provided support.

Around 80% of the diaspora organizations also noted having links to other entities in their respective country of origin (**Figure 1D**), which included universities, schools, research groups, associations, libraries, networks, national agencies for research, and embassies (of the country of residence in their country of origin). Events with organizations from other countries (i.e., not the country of origin or the country of residence) were also reported by 80% of participants (**Figure 1D**). Markedly, these events were mostly thematic scientific events (e.g., scientific congresses), with only two organizations reporting other themes like capitalization of scientific experiences or career opportunities.

In order to determine the engagement in SD practices, organizations were questioned explicitly on their participation in science policy or SD initiatives in their home country and implicitly through questions based on the "strategic approach" of SD by Flink and Schreiterer (2010). Sixty percent of organizations self-reported as being involved in science policy or SD initiatives (**Figure 2A**). **Figure 2B** contains a word cloud with the answers to the question of how these organizations had participated. These included direct contributions to public policy discussions, mediation with government for scholarship extensions, joint declarations with governments, publications, and collaborations, awareness of how science, technology, engineering and mathematics (STEM) can be harnessed for economic development and information visualization.

For the implicit approach, organizations were questioned about their activities and goals based on the three categories defined by Flink and Schreiterer (2010): Access, Promotion, and Influence (**Figure 2C**).

Regarding the type of SD activities reported:

- Access: 80% of the organization reported to be working toward improving their home country's innovation capabilities and competitiveness by creating access channels to researchers, research, infrastructure, new technologies and other resources.
- Promotion: 100% lead or participate in research and researchers' promotion activities, as well as network collaborations.
- Influence: 30% of the organizations communicate as one of their aims to use national science to influence decision-making in negotiations with actors in academia, civil society and the private sector outside their home country.

Together, these results indicate that highly-qualified diaspora organizations are active SD players, largely focused on promotion and access strategies.

Qualitative Results

After conducting the focus groups, the following results are presented.

INVECA

Network Features

This network stands out because of its governance and autonomy. It is an interdisciplinary and horizontal organization that uses democratic mechanisms for elections and has political autonomy. Its leaders serve in short 2-year periods and it builds on strategic alliances with key stakeholders in Germany. There is an important commitment and responsibility by each member, not only the leaders, to contribute to the network to help it develop.

Excerpts from interviews regarding network features:

-From the beginning there is a continuity effect. The network was founded in 2012; also supported by the Argentinean diaspora; it started with a model and it grew. The board periods last 2 years and new people bring fresh ideas. We have also had public funding. The embassy gives us funds for our annual meeting. Each generation of the board has had important milestones; legal status, bank accounts, we have positioned the network with strategic partners. (Participant 1).

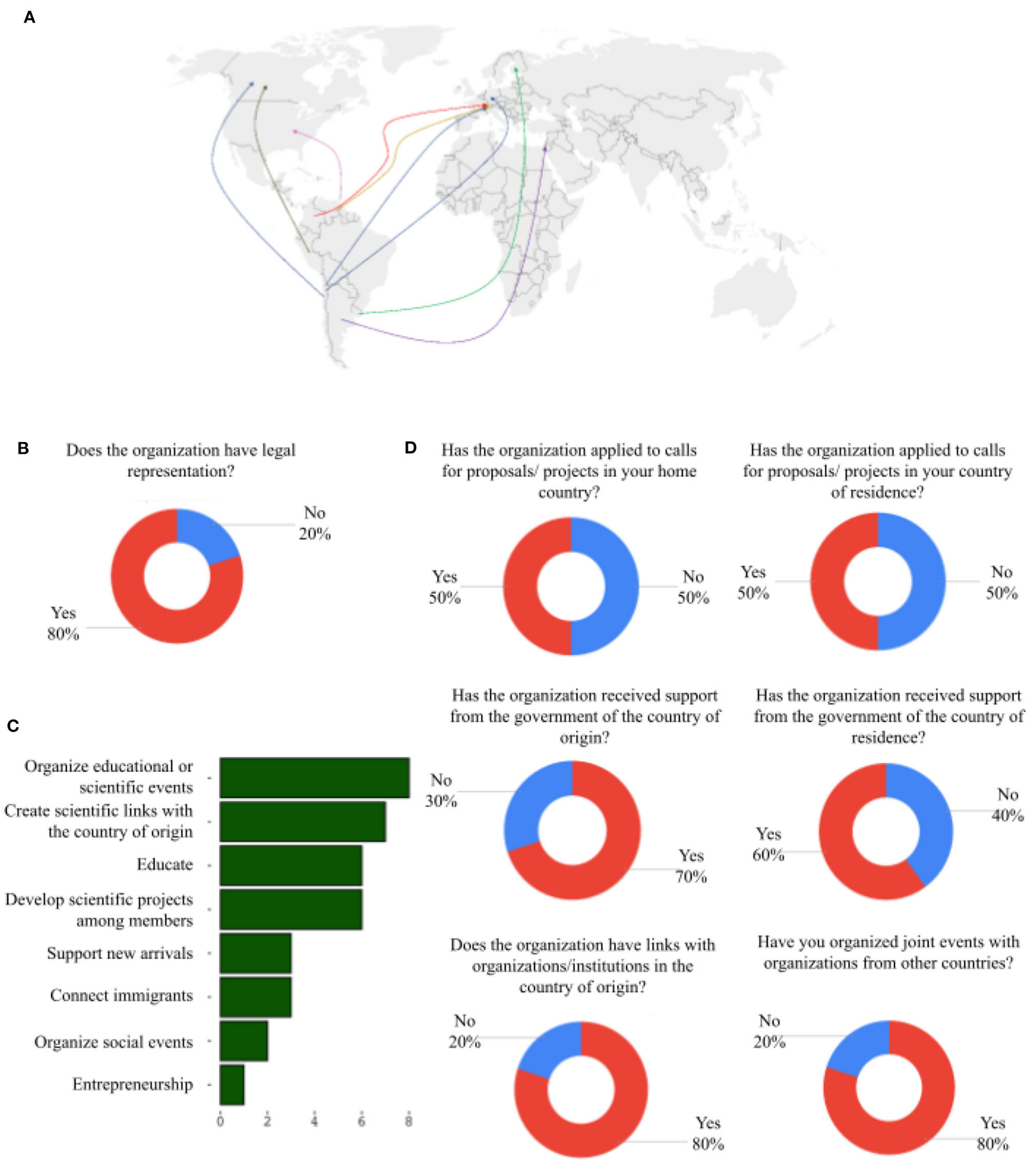

FIGURE 1 | Analysis of diaspora networks. **(A)** The 10 countries of origin and countries of residence of the diaspora networks that answered the survey (see **Table 2**). **(B)** Proportion of diaspora networks with legal representation. **(C)** Frequency of objectives stated by the diaspora networks surveyed ($n = 10$). **(D)** Relationship of diaspora networks to their country of origin and their country of residence.

-The autonomy of the network, political autonomy, which does not depend on the governments in power, the interdisciplinary nature of the network, the democratic mechanisms within the internal structure of the network, such as the leadership, with an expanded board where other members participate in relevant actions, and the strategic alliances with actors in Germany. This positioning in Germany has been very important. (Participant 3).

FIGURE 2 | Science diplomacy engagement of the diaspora networks. **(A)** Proportion of diaspora networks that self-employed engaging in science diplomacy activities. **(B)** Word cloud of answers to the question of how these diaspora networks engage in science diplomacy. Generated at https://www.jasondavies.com/ from translated answers. **(C)** Science diplomacy activities undertaken by the diaspora networks based on the definition of science diplomacy by Flink and Schreiterer (2010). Created by Datawrapper.

Conceptions of SD

The conceptions from this network refer to government-led activities involving researchers and the use of researchers for liaison with other countries. It includes the networking processes for science and facilitating scientific collaboration.

Excerpts from interviews regarding conceptions of SD:

I have an academic bias with that, I understand it as international activities, directed or planned by governments where other scientific actors are involved in the relationship with other countries. But, when it is described as "diplomacy" I associate it with governmental activity. (Participant 3)

A little bit of what our network does; facilitating scientific collaboration, and providing interaction activities between different actors in the community. (Participant 1).

Engagement Initiatives of the Diaspora With Their Governments

The interviewees indicate some of the activities linking the diaspora with their governments, namely the international cooperation programs in various fields, or the strategic alliances with government entities. This network refers to funds to organize activities with the scientific diaspora and the strategies for outreach scientific activities.

Excerpts from interviews regarding initiatives of the diaspora with their governments:

There are two forms of linkage; for example, the search for financing for network activities and generating strategic alliances with government entities, for example for the Chilean embassy in Germany. We have done some activities, for example, and we have been accompanied by Chilean government officials. (Participant 1)

Recommendations for Diaspora-Government Linkages

Building networks between diaspora and government entities is one of the key recommendations from this set of interviewees. Diaspora should present their activities to their governments. They also mention that governments should generate public funds for diaspora activities in support of funding annual meetings of diaspora networks. INVECA suggests the government-to-government transfer of good practices on diasporas.

Excerpts from interviews regarding diaspora-government linkages:

Positioning oneself vis-à-vis the government, presenting projects, activities; in our case, such as the annual meeting is a scientific activity, which has a return by allowing Chile to present itself in another country, in this case Germany, given that this is a public activity. This is an example of positioning. (Participant 2)

INVECA's results are presented below in **Table 3**, divided into the aforementioned categories.

TABLE 3 | INVECA's results.

Network features	Political autonomy
	Leadership in short 2-year periods
	Horizontal network
	Use of democratic mechanisms for elections
	Strategic alliances with stakeholders in Germany
	Interdisciplinary
Conceptions of science diplomacy	Government-led activities involving researchers
	Facilitating scientific collaboration
	Networking processes for science
	Use of researchers for liaison with other countries
Recommendations for diaspora-government linkages	Diaspora should present their activities to their governments
	Funding annual meetings of diaspora networks
	Generating public funds for diaspora activities
	Building networks between diaspora and government entities
	Government-to-government transfer of good practices on diasporas
Engagement initiatives of the diaspora with their governments	Funds to organize activities with the scientific diaspora
	Strategies for the outreach of scientific activities
	International cooperation programs in various fields
	Building strategic alliances with government entities

URUFI

Network Features

Despite URUFI having no legal status, it is a compact group with a shifting population and a defined mission and vision. It is officially constituted and network members consider it as an instrument of linkage and cooperation between Uruguayan university students, professionals and academicians in Finland.

Excerpts from interviews regarding network features:

URUFI does not have legal status and we are not officially linked to the government. What we have in practice is that the Uruguayan Embassy in Helsinki invites us to events and meetings, but it is not official.(. . .)The good thing is that we are a small, compact group and that we communicate very well. (Participant 4)

We have a mission, a vision, although we had some identity crisis at some point. We seek to be a group that is an instrument of linkage and cooperation between Uruguayan university students in Finland and to include all types of academics: university students, professionals and scholars. The goal is to include everyone. (...) URUFI has almost 5 years of validity. Our grouping is very mobile. (Participant 5)

Conceptions of SD

For URUFI the concept of SD has many meanings and there is no single definition. It can be defined as an interconnection between science, authorities' decisions—making positions, academicians, researchers, and networks, where ideas and projects are exchanged to improve the world.

Excerpts from interviews regarding conceptions of SD:

It is about relationships between universities, scientists and networks where ideas and projects could be exchanged to improve the world through this; it is a synergy. (Participant 5)

The concept has many meanings, there is no single definition...it is an articulation between science, the transmission of science in the world, but also another component of people who are in places where they can make decisions, such as politicians and authorities. (Participant 4)

Engagement Initiatives of the Diaspora With Their Governments

There are several initiatives led by URUFI but not defined as SD strategies. For example, there are alliances for research funding by ANII[3], the *Agencia Nacional de Investigación e Innovación*

[3]https://www.anii.org.uy

from Uruguay, or by "Uruguay XXI," an agency which is heavily involved in achieving the Sustainable Development Goals (SDGs). URUFI has also established contact with the Uruguayan Foreign Ministry for the participation in an event called "Active Citizenship for Development" which brought together qualified Uruguayan diaspora around the world in Montevideo.

Excerpts from interviews regarding diaspora engagement with their governments:

I can think of ANII, the National Agency for Research and Innovation. This organization has had many initiatives to finance research, especially in the area of doctoral studies, issues related to entrepreneurship (...). (Participant 4)

Events such as meetings, gatherings and others are held, in which we are invited by universities, the Uruguayan Foreign Ministry, among others. (Participant 5)

Recommendations for Diaspora-Government Linkages

URUFI believes that actions should be carried out organically and developed before being presented to governments for support or funding. URUFI thinks that it is possible to create a "Network of networks," to generate links and build bridges with the authorities of the Ministry of Foreign Affairs of Uruguay.

Excerpts from interviews regarding diaspora-government linkages:

In my personal opinion, a few years ago we contacted ANII and the Ministry of Foreign Affairs and at that time I do not know why we were unable to materialize the ideas we were putting forward, for example the "Network of networks" initiative (...). Then I thought we could do it the other way around. Instead of first going to the authorities to move an initiative forward, we first had to establish those links ourselves, such as the creation of the "Network of networks." We were in contact with an Uruguayan researcher in Barcelona with whom we have generated initiatives, ideas and a very fruitful connection and we also agreed with the idea that we must first create the links and then go to the authorities, because otherwise we might not be able to inspire enthusiasm in the governmental authorities, and this way we would do it more organically. (Participant 4)

URUFI's results are presented below in **Table 4**, divided into the aforementioned categories.

TABLE 4 | URUFI's results.

Network features	It has no legal status
	It is not officially constituted
	It operates physically at the invitation of the Uruguayan Embassy in Helsinki.
	Small and compact group
	Mobile grouping with 5 years of validity
	Clear identity of Uruguayan university students in Finland
	Defined mission and vision
	Instrument of linkage and cooperation between Uruguayan university students in Finland
Conceptions of science diplomacy	Relationships between academicians, researches and between networks where ideas and projects could be exchanged to improve the world through this
	It is an interconnection between science and people in decision-making positions, such as politicians and authorities.
Recommendations for diaspora-government linkages	Contact with offices of the Ministry of Foreign Affairs
	Creating a network of networks
	Generate links and then communicate with the authorities
Engagement initiatives of the diaspora with their governments	Research funding initiatives at ANII, the National Agency for Research and Innovation

CEVALE2VE

Network Features

CEVALE2VE was originally composed of Venezuelans in diaspora, but nowadays, it includes people of different nationalities who have a sense of identity and belonging to the network. Many of its members were trained in the same disciplines of knowledge (physics), this is why there is a previous link between them. CEVALE2VE has strength in fundraising, which has greatly contributed to the educational and outreach work of the network, especially with physics students in Latin America.

Excerpts from interviews regarding network features:

Initially we created CEVALE with only Venezuelans, but then we brought in people of other nationalities. Our idea is very simple: many of us did the same physics: particle physics. (Participant 6)

There were a number of funding sources. We learned how to apply for international projects (...). We created funding sources so that our students could do international internships. (Participant 7)

Conceptions of SD

One of the definitions provided by CEVALE2VE members indicates the use of the scientific role to open doors with decision makers in the political arena. They also stress the importance of collaboration between countries to strengthen STI and the creation of international networks for researchers. Emphasis is also placed on the role of the scholar as a diplomat, establishing alliances, and collaborations for science.

Excerpts from interviews regarding conceptions of SD:

It sounds to me like taking advantage of the doctoral degree we have to get closer to those who make public policy. (Participant 6)

Networking, building knowledge, and establishing relationships. We have always had colleagues coming and going. If you imagine SD from the frontiers, it's a rather natural process. (...) SD changes from its context; building collaborations and knowledge between different cultures. (Participant 7)

Engagement Initiatives of the Diaspora With Their Governments

The interviewees indicated that through government funded doctoral scholarship programs they have been able to get training abroad and some of them have returned to their country of origin. This allowed them to participate in high-level training and to strengthen the relationship with countries that have good international links. Given the political situation in Venezuela, CEVALE2VE's relationship with its country of origin has been mainly with universities.

Excerpts from interviews regarding initiatives of the diaspora with their governments:

> *(...) Many people were trained and came back with those scholarships such as BECAS FUNDACIÓN GRAN MARISCAL DE AYACUCHO; the most important thing is that it helped to generate connections. (Participant 9).*

> *There have always been scholarship systems to interact with countries, which have developed very good relations. (...) Now we have an Erasmus project where there are eight universities from Latin America. This scalability made it possible to bring in other people and countries. High-performance physicists are also accustomed to tribalism. To be together. (Participant 6)*

Recommendations for Diaspora-Government Linkages

CEVALE2VE recommends removing the stigmas related to the diaspora, recognizing its value and the actions it has been developing with and in other cases without the support of the government. They also highlight the potential of creating the conditions to work in and for the country, promoting remote actions to enhance STI through virtual means. On the other hand, they consider open science as an engine for the collaboration between countries; they also mention the contribution of the diaspora to generate connections outside their country of origin, which can be of great importance for the development of STI systems.

Excerpts from interviews regarding diaspora-government linkages:

> *You have to start by talking; get to know the diaspora and see what they are doing (...); you have to start with dialogue. (Participant 8)*

> *Venezuela has a very special scenario. The first thing is to create conditions. You are trained abroad and there is no place where you can work or have a decent salary. It is important not to see the individual who is abroad as someone who failed and left everything behind; with virtuality you can establish meaningful connections with scientists. (Participant 9)*

CEVALE2VE's results are presented below in **Table 5**, divided into the aforementioned categories.

TABLE 5 | CEVALE2VE's results.

Network features	Giving back to the country
	Identity and sense of belonging
	Previous connections among participants
	Collaboration with diasporas of diverse nationalities
Conceptions of science diplomacy	Collaboration between countries for STI
	Creating international networks for researchers
	Contact between researchers and public policy
Recommendations for diaspora-government linkages	Encouraging the establishment of consortia for STI
	Creating conditions to work in and for the country
	Engaging politicians with researchers
	Fostering remote actions on STI
	Diagnosis of the diaspora and the actions it carries out
	Open science as an assembling engine among countries
	Links with the diaspora through the universities
	Removing stigmata related to diaspora

DISCUSSION

Scientific diaspora organizations are primarily connected to SD as evidenced in the results, from an approach of "Access" (Flink and Schreiterer, 2010) to laboratories, training, capacities, good practices in STI, and also from the dimension of "Promotion" (Flink and Schreiterer, 2010), by promoting science and training carried out in the country of origin. As evidenced in the previous section, for the scientific diaspora organizations interviewed, SD is mainly about connecting researchers, creating alliances between countries to promote STI and using science to support decision makers. In this sense, from the perspective of scientific diaspora organizations, SD is about establishing bridges between their country of origin and the host country to advance science. However, this conception is not clear to governments, since there is a lack of consistent and sustainable policies and programs to involve the organized scientific diaspora, as has been shown throughout this article.

Scientific diaspora organizations seek to support national interests, but also those of regional and global nature (Gluckman et al., 2017), mainly through significant scientific alliances. However, one of the most present manifestations in this study is that the diaspora actively collaborates with the capacity building of personnel in their country of origin (Arunachalam et al., 2017), but also the important support provided by the diaspora for individual researchers or networks in their international scientific engagement process. Definitely one of the outcomes observed in this study is the support carried out by the scientific diaspora for the establishment of scientific collaborations and international cooperation projects, where it can contribute to remove barriers, both cultural, scientific and technical, with counterparts, especially those located in countries of the Global North.

Something present in diaspora organizations is the interest in giving something back to the country of origin, especially in terms of capacity building, but also in terms of networking and outreach. As governments have not been consistent in their relationship with the scientific diaspora, these organizations connect with non-governmental actors, as seen in the case of

CEVALE2VE, who have an important involvement with higher education institutions.

According to López-Vergés et al. (2021), there are no consistent channels of communication with the scientific diaspora, and many of the public policies are not directed to organized diaspora. This is troublesome, because as we observed in the results, the organized diaspora mainly wants to seek an effective and long-term engagement with their country of origin, but from outside those countries. As observed in the results, a generalized problem in this region is the lack of quality working conditions that allow the recruitment of highly qualified diaspora; this has caused that policies oriented to "brain circulation" have not been successful in the region in the long term. In this sense, the "brain linkage" approach proposed by Tejada et al. (2013) is the most effective for LAC and other emerging economies, as it takes advantage of the potential of the diaspora in terms of networking, connections, knowledge transfer and support for public policy and even the development of innovation in the business sector. Moreover, support to the organized diaspora can be enhanced so that it can advance and become a diaspora network, with actors from the country of origin as well as the host country and even others, favoring the flow of knowledge supported by virtuality (Grossman, 2010), as observed in the case of CEVALE2VE.

Based on the review carried out, networking, scientific collaboration and joint projects are the foundation of scientific diaspora networks. Providing scientific advice and forging links with the governments of their countries of origin are only indirect or utilitarian (financial) purposes. The evident benefits of scientific diaspora organizations are related to the support among network members. The use of virtual tools is a practical approach to link the scientific diaspora with national issues and facilitate knowledge exchange.

RECOMMENDATIONS AND POLICY IMPLICATIONS FOR DIASPORA ORGANIZATIONS AND ITS GOVERNMENTS

Based on the evidence provided by the diaspora organizations participating in this research, a set of recommendations for diaspora organizations and the national governments interested in strengthening the interaction with the diaspora are presented in this section. This set is within the schemes of SD and it could strengthen some of the still under construction policies for SD in LAC.

Recommendations for the welfare of the diaspora organizations have been divided in seven categories:

- Mission and vision: defining a clear mission, vision, and organization values is important to establish the identity of the organization and generate a sense of belonging in their members. Clear definition of the role of each member inside the organization. Flexibility, as in many cases the participation in the organization is done in their free time. Recognition of the work of each member.
- Governance: create horizontal, non-partisan, democratic, and rotational governance to ensure active participation in development and decision-making of the organization. To ensure independence from governments, it is crucial not only to avoid partisan statements when discussing science policy but also to secure third party funding.
- Education: competences and needs of the members of the diaspora organizations should be assessed in relation with SD. This will enable the identification of suitable training on SD for the organization.
- Collaboration/relationships: strengthen the collaboration with origin and home countries governments, academic institutions, embassies and other diaspora organizations to exchange best practices. Training on SD can be targeted and more effective in terms of alliance with government and public policy development.
- Communication: outreach activities to communicate objectives and results from the diaspora organization, making the organization findable. Make use of remote/online communication tools for strengthening relationships with home countries and promote social interaction.
- Open use of resources: ensure transparent accessibility to organization resources and reusability of resources through coordinated efforts.
- Sustainability: search for funding, links with governments and other third party organizations (see relationships).

As for the governments willing to further enhance the scientific diaspora in line with the brain linkage approach, we propose the following recommendations and policy implications based upon the results of this research:

- Count: generate an inventory or diagnosis of a country's scientific diaspora and their actions.
- Create: fund calls to support the activities of the diaspora organizations and or collaborations between national and diaspora organizations. Improvement of conditions to work in and for the country.
- Collaborate: Involve the scientific diaspora organization to contribute to scientific policy development, strategies on SD, events, activities, etc. Collaboration programs between national and diaspora communities at the academic and government level. This collaboration should not compromise the independence of the scientific diaspora organizations, they should retain their ability to operate in a manner that is insulated from the influence of political actors.
- Recognize: recognition of the role of the diaspora in the scientific development of the countries.
- Share: transferring good practices from government to government related to scientific diasporas. Promoting open science as an assembling engine among countries.

CONCLUSIONS

Diaspora organizations from LAC engage with government and non-state actors and are active SD players by promoting the scientific developments of their country as well as by enabling access to research resources through links between their country of origin and their country of residence. These efforts are mostly done implicitly without a clear SD strategy. Indeed, the study confirmed that the definition of SD remains vague and ambiguous in these groups. Nevertheless, these diaspora organizations have complex structures, networks and projects that have benefited their country of origin as well as their diaspora members.

In cases where there are not enough diaspora networks related to a given country, a regional one could be generated or the creation of a network of networks could be encouraged, enhancing diaspora development in the framework of regional blocs. The lack of economic resources and political strategies implies that science still plays a secondary role, STI policies have been adjusted to the political-economic reality of each country, characterized by significant periods of uncertainty and instability. Government plans and public policies should include provisions to support qualified diaspora organizations working on an internationalization strategy for STI, facilitating spaces for diaspora participation in STI ministries, as well as government agencies and the Ministry of Foreign Affairs.

The LAC region as seen in the qualitative and quantitative data of the study is a clear reflection that the interest to maintain links with the country of origin does not emanate from the States, which leads us to reflect on the need as a region to establish public policies that allow sustainability in the collaborations with the States. As mentioned before, for the organized scientific diaspora SD is about creating bridges between the host and home country to advance STI. We need a more homogeneous and balanced growth between the scientists who return to their countries of origin and those who settle in the host countries, and rather than a loss of talent, guarantee gain and exchange of opportunities, such as those presented in the recommendations.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Mexican Scientist Diaspora in North America: A Perspective on Collaborations With México

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Scientific diasporas from developing countries represent an opportunity to strengthen international collaborations. These collaborations build upon the desire of members of the diasporas to establish scientific, academic, technological, and cultural exchange networks with the communities in their country of origin. While Mexico has a significant number of scientists residing abroad, particularly in North America, and most of them are committed to aid in the country's development, institutional coordination has not harnessed its benefits. In this work, we present an analysis of initiatives carried out by Mexican scientists, members of the diaspora, studying or working in the United States of America and Canada. The study is based on a set of interviews with members of this diaspora. We asked scientists about the conditions that enabled or obstructed their initiatives back in Mexico, and we discussed the role of these factors for capacity building. We also provide general recommendations to enhance contributions to the advancement of science in the country.

Keywords: scientific diasporas, brain drain, Mexican scientists, United States, Canada, international collaborations

INTRODUCTION

Knowledge has become the main input for economies that aim to increase productivity and global competitiveness (Castells, 2000). Indeed, in this so-called Knowledge Economy, scientists play a key role (World Bank., 2013). Thus, in terms of the investment made by a country to possess a qualified labour force, emigration represents a loss of human capital that undermines opportunities for its development. In this regard, the concept of brain drain has been introduced as "the permanent emigration of skilled persons from one jurisdiction to another" (Tigau, 2009, p. 49) or, in terms of qualification, it is defined as "the output of those who have at least a university degree, with at least 15 years of schooling, in areas of science or technology and who work in those fields" (Martuscelli and Martínez Leyva, 2007, p. 4). Indeed, brain drain is usually regarded as a problem for developing countries, like Mexico, since it implies the reduction of a scarce type of workforce: people with hard-gained know-how.

Although brain drain implies a loss of skilled labour, it can also become an agent of international cooperation and development (Tejada, 2012; Jarquín-Solís, 2022). This can be key for developing countries with an output of scientists moving abroad since their collaborations with public administrators, business communities, and research organisations have shown to support robust innovation environments (UNCTAD., 2017, p. 17). In this context, scientific diasporas have been defined as "self-organised communities of expatriate scientists and engineers working to develop their home country or region, mainly in science, technology, and education" (Barré et al., 2003).

Scientific diasporas consider people that "have been integrated into the labour, social and cultural dynamics of the country where they live, but who are willing to collaborate in the establishment of scientific, academic, technological and cultural exchange networks with the communities of their place of origin" (Martuscelli and Martínez Leyva, 2007). Scientific diasporas can play an important role in leveraging migration's benefits because they carry opportunities for international collaborations to promote knowledge networks and capacity building for the countries involved. For example, diasporas from Colombia, India, and South Africa have shown successful results in proposing public policies, training human resources in science and technology, and, in general, building capacities for the development of their country of origin (Martuscelli and Martínez Leyva, 2007).

The case of the Mexican diasporas is of particular importance. Mexico is the second country with the highest emigrant population in the world, and the first place in Latin America (McAuliffe and Triandafyllidou, 2021). As of 2020, around 11 million people had emigrated from Mexico most of them to the United States of America (USA) (McAuliffe and Triandafyllidou, 2021). It is estimated that in the coming years, Mexican emigration will continue to increase, although not in a sustained manner (Secretaría de Gobernación., 2022). According to the Mexican National Council of Science and Technology (CONACyT), between 1990 and 2015 around 1.2 million Mexicans with graduate and postgraduate degrees left in search of better opportunities abroad (OECD, 2020 cited in Rogozinski, 2020). This is a significant number considering that around 80 percent of the Mexican population does not hold a university degree (OECD, 2020 cited in Rogozinski, 2020). The main "receiver" of these migrants is the USA, where around 80% of all Mexicans abroad live (McAuliffe and Triandafyllidou, 2021). Gaspar and Chávez (2016) reported that 13.4% of all Mexicans with postgraduate degrees in the USA perform in the field of basic sciences.

In Mexico, few initiatives have benefited from the Mexican diaspora, and fewer have exploited it. One of them, which includes the USA and Canada, is the Red Global MX (Global MX Network), formerly the Red de Talentos Mexicanos en el Exterior (Network of Mexican Talents Abroad), a governmental institution established in 2006 through joint work between the Institute of Mexicans Abroad of the Ministry of Foreign Affairs (or Instituto de los Mexicanos en el Exterior-IME), the Ministry of Economy, and the CONACyT. The Global Mx Network brings together individuals interested in promoting the development of Mexico, with a particular focus on inserting Mexico into the knowledge economy. It is organised in local chapters, autonomous in terms of management and action (Gaspar and Chávez, 2016).

As of 2022, the Global MX Network is made up of 71 Chapters in several countries around the world and 19 Nodes in different states of Mexico. It has more than 6,500 active members in 34 countries (RGMX Capítulo Países Bajos, 2020). A Global Coordination of the Network connects the performance of the chapters, although there are also four Regional Coordinations: Canada, USA-Latin America, Europe, and Asia-Oceania, which are responsible for assisting the organisation of the Chapters regionally and representing the network before national and foreign institutions, as well as serving as interlocutors with the IME (RGMX Capítulo Países Bajos, 2020; RGMX Capítulo Portugal, 2022).

Each Chapter and Node procures its own resources. They possess autonomy of management and action to participate in national and international initiatives. They also have elected Board of Directors, and define their own rules, work plans and objectives. Nonetheless, it is expected that they work in four strategic sectors: (1) Science, Technology, Research and Academia; (2) Entrepreneurship and Innovation; (3) Social Responsibility; and 4) Creative Industries (RGMX Capítulo Países Bajos, 2020; RGMX Capítulo Portugal, 2022). Some Chapters have, in addition to undertaking projects in these sectors, other programs to support the quality of life of Mexicans abroad and to promote Mexican culture (RGMX Capítulo Países Bajos, 2020).

Another initiative around the Mexican diaspora in North America is the Confederation of Mexican Graduate Students and Researchers in Canada, a non-governmental organisation established in 2006, whose motto is "Creating community networks of specialists for the promotion of culture and academic exchange between Mexico and Canada". Its general objectives are: (1) To guide Mexican students, researchers, and professors, (2) To create a network of contacts that includes students, researchers, government, and industry, in order to facilitate academic and employment opportunities both in Canada and in Mexico, and (3) To inform and support the academic community, as well as cultural and altruistic activities that allow transmitting Mexican culture (CEIMEXCAN, 2014).

The opportunities posed by the movement of scientists, whether in natural or social sciences, as well as humanities conducting empirical research, from México to the USA and Canada, is precisely the topic of this article. This paper examines collaboration experiences of members of the Mexican scientific diaspora in North America. We aim to understand the role of the scientific diaspora in leveraging knowledge networks and building multinational science, technology, and innovation environments that promote development in Mexico. We analyse the importance of enablers, challenges, and barriers that scientists encountered when establishing scientific collaborations.

The article is organised as follows: in Methods and data we describe the methods and data collected and used for the study, namely an initial questionnaire and a set of interviews with members of the Mexican scientific diaspora; in Findings we present the results of the analysis focusing on identifying enablers or obstructors of collaborations between members of the diaspora and initiatives in Mexico; in Discussion we discuss the results, and give some final remarks.

METHODS AND DATA

In this research, members of the Mexican scientific diaspora are considered people who recognise themselves as Mexicans and possess postgraduate studies in science and technology, whether natural or social, as well as humanities conducting empirical research, and who are currently living in the United States or Canada. This work is indeed a perspective of the mobility of qualified Mexican human resources in the northern region of the continent and the opportunities for multinational collaborations. Thus, this qualitative analysis commences with an initial questionnaire that collects demographic data on the Mexican scientific diaspora in North America and continues with interviews with those who accepted the invitation to participate in them.

The sample presents the difficulty of having no exhaustive database that gathers Mexican scientists in North America. However, there are several networks where members can join at will, given that each network successfully reaches its target population. The networks used to reach members of the diaspora were both formal (Delegación general de Québec en México) and informal, as well as social networks (Twitter, Facebook, and LinkedIn). As a result, 29 scientists responded to the initial questionnaire, and nine of them were interviewed.

The median age of respondents was 35 years; 61% identified themselves as female, 36% as males, and 3% as non-binary. Regarding the country of residence, 71% reside in the USA and 29% in Canada. The median time of residence of the respondents is 5.7 years in their corresponding country. Most of the scientists that answered the questionnaire hold a postdoctoral researcher position, but other types of research positions, as well as postgraduate students also participated in the initial survey. One of the respondents performs as a consultant and as a postdoctoral researcher. Most respondents perform within the academic sector (see **Figure 1**), and most of them do so in Medicine, Health Sciences, Biology, and Chemistry (see **Figure 2**). Note that the respondents were able to select more than one option as an answer for these questions.

In the next stage of data collection, interviews were conducted with respondents that agreed to comment further on their situation as members of the diaspora. The interviews were based on open questions, which made it possible to delve into the reasons for migration, as well as opinions on the obstacles and enablers of collaborations with stakeholders in Mexico. The guiding questions for the interviews were the following:

- Could you describe your professional training?
- Could you describe the two main reasons that determined your decision to move to your current residency?
- Could you describe your collaboration attempts with Mexican initiatives?
- According to your experience, what do you consider to be the main challenges in establishing successful collaborations with Mexican initiatives?
- In your opinion, what do you consider enables collaborations with Mexican initiatives?
- Do you consider it helpful to have an institution dedicated to permanently lead, manage, and implement collaborations between Mexican scientists abroad and initiatives in Mexico? If so, how do you envision such an entity's functionality?
- Do you have any additional comments, observations, or suggestions?

All interviews were recorded, and data was collected. However, this information is not published for protection of personal data.

Five of the nine interviewees identify themselves as women and four as men. Their time residing outside of Mexico ranges from 2.5 to 7.5 years. While three of them live in Canada, the remaining six live in the USA. Eight interviewees hold a Ph.D. and work in postdoctoral positions, and only one is still in graduate school. Two scientists work in medicine and health sciences; two in biology, chemistry, medicine, and health sciences, two in social sciences; one in biology, chemistry, and engineering; one in social sciences and applied statistics; and one in physics, mathematics, and earth sciences.

FINDINGS

The initial questionnaire allowed us to survey the attempts of the diaspora to collaborate back with Mexican initiatives, as well as the sense of need for additional mechanisms that facilitate such efforts, before performing the interviews. When asked about the attempts, successful or not, 77% of participants stated that they have tried to collaborate, while the rest admitted not having tried. Regarding the need for mechanisms other than existing ones, the position was somewhat divided, with 48% stating the sufficiency of existing mechanisms, 40% expressing the need for more mechanisms, and 12% admitting not being sure.

Nine respondents of the initial questionnaire agreed to be further interviewed. In what follows, we will describe the answers received during these interviews. It is worth mentioning that the interviews were performed in Spanish. We show the number of responses corresponding to each category in parenthesis.

First, when asked about the reasons to move outside of Mexico, participants commented the following as their main reasons: search for academic growth (4), lack of opportunities for specialisation (3), lack of professional working options (2), and lastly, personal reasons (1).

Regarding attempts to collaborate with Mexican initiatives, it is noteworthy that participants preferred collaborations with Mexican institutions in the form of academic projects (8). Other answers included projects with non-governmental organisations (NGOs) (2), with governments (2), and with industry (1). Participants mainly expect to produce high-impact scientific publications and to participate in conferences on their area of specialisation as products of their collaboration.

FIGURE 1 | Sectoral distribution of respondents of the initial questionnaire.

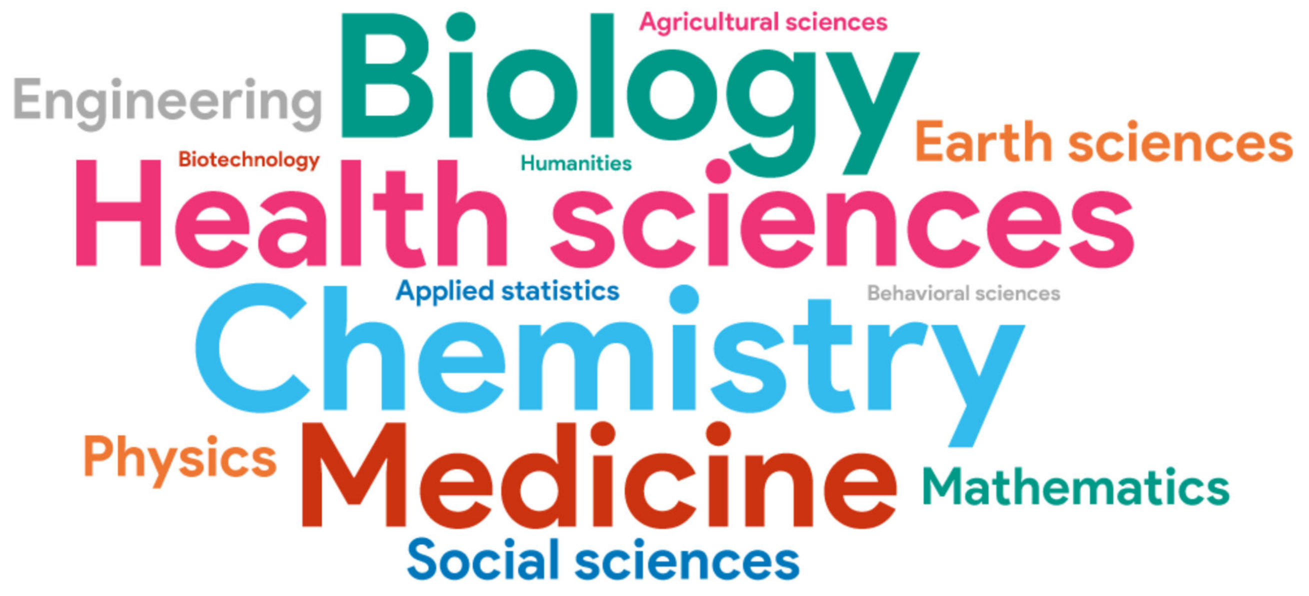

FIGURE 2 | Area of specialisation of respondents of the initial questionnaire.

Participants were also asked about the main challenges they faced while establishing collaborations with Mexican initiatives to elaborate on what hinders cooperation. Respondents identified a lack of knowledge of the available mechanisms, mismatch of timelines between academic and non-academic activities, and difficulties in setting common goals and objectives as the main obstacles to successful collaborations.

According to the experience of one of our interviewees:

"… academic collaborations between Mexico and the USA are easier because there is a common goal: conducting research. In the case of NGOs there are many areas of opportunity and opportunities for synergy, considering the experience of both parties. In this case, the most complicated is establishing common goals and schedules, because timing in NGOs and/or the government are rather different, maybe they need short-term results, while research results take longer."

The interviewees also pointed out that in most cases, these reasons are enough to result in a loss of interest by one of the parties, leading to the cease of the project. Other obstacles noted include the inefficiency of bureaucracy in both Mexican, and American or Canadian institutions, lack of funding and economic incentives, poor soft skills, and difficulty in locating collaborators, mainly due to missing institutions dedicated to supporting initiatives of Mexicans abroad. Some participants mentioned that bureaucracy hinders the formalisation of collaborations agreements and affects the success of the ones previously established.

When we look at enablers of collaborations, according to the experiences of most interviewees (8), previously established professional and personal networks are of primary importance. Scientists who lacked these networks found it hard to advance their partnerships. For example, one interviewee stated:

"… the collaborations where I have participated, have occurred because collaborators are my friends, and because they are mainly acquaintances from my master's or bachelor's studies, that is how the relationships are built. In the case of people who have contacted me after giving me an internship, it is worth noting that most of them come from abroad, from other Latin American countries, for example, Colombia, but they have never contacted me from Mexico except when there are previous relationships…"

Another respondent who has worked directly with the Mexican government at the national and state levels said:

"... the complicated thing is to have a point of contact to establish a communication channel, I think I had the advantage and the fortune of having worked in the federal public administration... and my job had great exposure to people who are in key positions. That allowed me to have certain points of contact when I went to study for a doctorate. It was a privilege to have met those people because otherwise I would have to knock on doors."

Finally, participants were asked about the necessity for a third-party liaising with Mexican scientists in North America and stakeholders in Mexico. Most interviewees agreed that an NGO (7) would be more suitable than a government office (1) due to the need for more direct and close cooperation. In addition, the interviewees consider that lasting collaborations and agreements are more fruitful if these do not depend on political circumstances, mainly because of a deficient follow-up by Mexican administrations. In the words of one of our respondents:

"... coming from the government there is the advantage of funding, but I consider that, independently of who is in the government at any given time, someone is always left out. On the other hand, coming from the civil society as an NGO there is the advantage of inclusion because there are no other interests but the ones from the own society..."

Remarkably, participants were eager to collaborate back with Mexico, mainly in the areas of the advancement of science and the promotion of scientific opportunities abroad. It is also worth mentioning that scientists reached through the survey belong to a specific subset of the Mexican scientific diaspora in North America: early-career scientists from certain knowledge areas who have rather recently left Mexico (no more than 10 years), mostly seeking better working conditions and opportunities in the USA and Canada.

Scientists surveyed showed interest in maintaining ties with Mexico through international collaborations. They seek to obtain personal and professional growth; to develop a multinational science, technology, and innovation environment; and harness science results for societal benefit in Mexico, Canada, and the USA.

DISCUSSION

Cooperation between nations is essential in some areas, whether it be economic, cultural, environmental, or academic (Johnson, 2015; Jorge-Pastrana et al., 2018). Even more, diasporas can be part of a new form of governing through responsabilisation of their welfare and that of their communities (Kunz, 2010). Scientific diasporas can be key agents in starting, growing, and sustaining cooperation in the form of concrete initiatives (Marmolejo-Leyva et al., 2015; Valenzuela-Moreno, 2021). This becomes particularly relevant when diasporas come from developing countries like Mexico, where its members could be regarded as promoters of collaborations rather than just part of the brain drain. This study explored the views of 29 members of the Mexican scientific diaspora, who work or study in the USA and Canada, providing a description of their initiatives and an analysis of the challenges and barriers encountered by them.

Although migration has been studied from different perspectives, this work focuses on the attempts of emigrants to establish collaborations back with Mexico. It is generally considered that brain drain occurs because satisfactory conditions are not found in the country of origin and/or that conditions in the country of destination are regarded as better (Giannoccolo, 2009). Answers from the scientists interviewed confirm this observation.

Respondents stated that there is significant interest in the Mexican scientific diaspora to collaborate with Mexico, mostly within their area of expertise. When attempts have been made to collaborate, previously established personal networks were commonly used. Thus, the interviews also confirmed the dichotomous situation of emigrants, who feel committed to the country that has welcomed them but maintain strong ties of identity with their country of birth (Martuscelli and Martínez Leyva, 2007).

We observed that academic collaborations are the most frequent type of collaboration carried out by respondents. This situation can be due to the fact that the current assessment of scientists in Mexico prioritises academic production in the form of research articles over other activities (CONACyT, 2020). The type of collaborations reported by interviewees is in line with what is expected for Latin American countries, such as increasing mobility opportunities for students, publishing papers with colleagues in their country of origin, participating in science communication activities, and linking knowledge with private, public, and non-governmental organisations (Bonilla, 2022).

There is also an outspoken interest from respondents to help increase the training of new human resources and improve opportunities for young Mexican scientists abroad. However, commitment from a few enthusiastic and knowledgeable, yet isolated, agents is not enough. Support in the form of coherent, coordinated, and collaborative institutional commitments, as well as relevant stakeholders' involvement have shown to be of grave importance (Tettey, 2016).

It is also noticeable that respondents declared that there was no institutional follow-up of successful collaborations between Mexican and foreign institutions, neither from Mexico nor from institutions abroad. This translates into difficult conditions for coalitions to promote effective collaboration and build sustainable community change (Goodman et al., 1998). Scientists interviewed identified an NGO as a desirable option to help avoid drawbacks of government initiatives, such as lack of continuity, impersonality, bureaucracy, and even unwillingness. Such an option implies the self-organisation of a multinational scientific community to aid Mexican administrations that, so far, have not successfully coordinated the efforts of the country's scientific diaspora.

The respondents also recognise a lack of so-called soft skills as an obstacle that affects the commencement of collaborations; agreement of goals, timelines, and responsibilities; and the way the team deals with administrative requirements. Indeed, soft skills are key since collaborative capacity is highly influenced by existing skills and knowledge, the attitudes that members bring, and the efforts made to build, support, and access this capacity (Foster-Fishman et al., 2001).

It is remarkable that more formal mechanisms to communicate and collaborate, such as permanent exchange programs (Kramer and Zent, 2019), specific financing for collaborative projects (Science Fund of Republic of Serbia SFRS., 2019), a scientific diaspora networking or a platform registration (European Commission, 2022), were not mentioned by the respondents. These mechanisms can be developed to support institutions focused to engage and improve Mexican scientific diaspora's initiatives, e.g., (Bravo and De Moya, 2018; Martínez-Schuldt, 2020; Sánchez and Cantú, 2021). As we have seen in the introduction, some formal mechanisms exist, but neither these nor other ones were mentioned by the interviewees.

Even though a significant number of Mexican scientists reside in the United States or Canada, few studies present updated and reliable data about this diaspora. This could be due to the methodological, organisational, and financial challenges of this type of studies. As a contribution to better understanding the opportunities posed by the Mexican scientific diaspora, we have examined the experiences and attitudes of some of its members towards building collaborations with their country of origin. This study invited members of the diaspora by means of formal and informal channels. Yet, a low level of response was registered in both the initial survey (29 participants) and the ensuing interviews (9 participants). Further efforts to reduce drawbacks and efficiently direct initiatives that connect Mexican scientists abroad are needed, particularly in North America.

While the Mexican scientific diaspora in North America exists, it is not yet fully studied and understood as a societal and technological phenomenon that can harness its importance in the dynamics between the countries. To take advantage of the opportunities of possessing a valuable scientific diaspora, Mexico can implement mechanisms that identify, connect, and cohere emigrated scientists towards the common goal of contributing to its scientific and technological development. These mechanisms can profit from connecting members of the diaspora and the scientists residing in Mexico, as well as strengthening existing ones. Given that promoting science and technology in the best possible manner is the goal, we believe this could greatly enhance collaborations and advance science, notably in countries where it is most needed.

DATA AVAILABILITY STATEMENT

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

AUTHOR CONTRIBUTIONS

All authors listed have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Engaging the Guatemala Scientific Diaspora: The Power of Networking and Shared Learning

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The underdevelopment of the higher education system in Guatemala and the fragility of its science and technology (S&T) contexts have compelled a significant number of talented Guatemalan scientists to be trained, educated, and employed abroad. The relocation of such skilled human power to different countries and regions has resulted in a growing Guatemalan Scientific Diaspora (GSD). Until recently, the emigration of scientists from the Global South to scientifically advanced countries in the North was studied as it negatively impacted the countries of origin. However, technological upgrades and globalization have progressively shifted the paradigm in which such scientific diasporas interact and connect, thus enabling them to influence their home countries positively. Due to the lack of knowledge-based evidence and functioning connecting platforms, the value and potential of the GSD in their involvement in proposing solutions to complex socio-economic, environmental, and other challenges faced by Guatemalan society remain unknown. Moreover, the lack of interaction of relevant stakeholders (S&T policy agents, international partners, higher education institutions and research centers, industry, and relevant not governmental organizations) represents a pervasive obstacle to the untapped impact of the GSD in the country. This study outlines the Guatemalan scientific diasporas' networking as a mechanism for building research excellence and intellectual capital. This force could respond to the need to strengthen the national science capacities and meet the demands for knowledge production and access to broader sectors of society. This research applied qualitative methodology that, through the conduction of focus group discussions and semi-structured interviews with members of the Guatemalan scientific community and relevant key stakeholders, delved into the existence and articulation of the GSD and potential stages for their engagement with their country of origin. Findings highlight the importance of digital and technological pathways that might leverage the GSD's knowledge and experience, channeling skills, and international connections for better interaction with the Guatemalan society. Furthermore, the discussion addresses how technology might turn brain drain into brain circulation, enabling the articulation of the GSD as a viable opportunity to generate collaboration between scientists abroad and local actors, ultimately impacting the building and development of Guatemalan science and national research capacities.

Keywords: science diasporas, S&T policy, S&T capacity building, Guatemala, diaspora knowledge networks, skilled migration, OWSD, brain drain-brain circulation

INTRODUCTION

Guatemala is a developing country located in the Central American region. It is categorized as an upper-middle-income economy with a Gross National Income per capita of US$4,603 (World Bank, 2021). Although it is the largest economy in Central America, the limited scale of its geographic area (108,800 km^2) and relatively small population reported at 15 million (Censo Población, 2018) pose challenges in terms of the development and strength of the national scientific and research context. Despite its growing economy, Guatemala is a country with poor development indicators with limited local economic opportunities; thus, international migration is an option that -at the individual and household level- is perceived as an opportunity to improve the home economy (Saenz de Tejada, 2009; Canales et al., 2019). Moreover, during the internal civil conflict (1966–1996), there were massive emigration waves of Guatemalans, especially from the most affected areas (i.e., the highlands and rural areas) to Mexico and the United States of America (ICEFI, 2021). This international migration included scientists, lecturers, and intellectuals subjected to political persecution. In other words, a combination of lack of work training and job opportunities, and a violent and hostile local context, have produced a constant exodus of Guatemalans (both low and highly skilled human resources). Canales et al. (2019) have estimated the loss of nearly 30.0% of highly skilled Guatemalan migrants, doubling the 13.5% estimated in Commander et al. (2004). Admittedly, the deepening of globalization, the emergence of a digital era, and advances in technology have resulted in the possibility of turning such loss into opportunities, particularly considering frequent and multiple networking collaborations.

Migration of Highly Skilled Human Capital

According to the Organization for Economic Cooperation and Development, OECD (2016), there is increasing global competition for talent, reflecting that highly educated individuals participate in mobility schemes and are prone to emigration. It is possible to identify strategic international open networks that attract foreign talents to reduce skill gaps, particularly for smaller or lower-income countries. Scientific and research migrations have become more complex in the global landscape, making high- and low-income countries pay more attention to policies that offer more attractive conditions to support inward, outward, and return migrations. However, the "brain drain" paradigm continues to be dominant in the literature when addressing the mobility of skilled human capital from the Global South to the North (Brown, 2002; Davis and Weinstein, 2002; Commander et al., 2004). Brain drain has consolidated as a critical issue for developing countries that struggle to position themselves in the global market. According to Brown (2002), globalization changed the global economy from more labor-intensive to more knowledge and technology-intensive industries.

High development indicators, along with the country's size and proximity, are among the main determinants of emigration, for which small and developing countries observe the highest rates of skilled emigration (Docquier et al., 2007; Docquier and Rapoport, 2012). The primary motivations of scientists and academics to migrate include having access to higher scientific and technological infrastructure and career opportunities and, to a lesser degree, a higher human development index (Siekierski et al., 2018). In the past, the relocation of such valuable human power from the Global South to scientifically advanced countries was considered to negatively impact the countries of origin, as reflected by it being termed "brain drain": a loss in highly skilled human capital. Nevertheless, technological evolution has changed the paradigm in which such scientific diasporas interact and connect, thus enabling a positive influence on the development of the country of origin. Indeed, the current trend regarding these migration patterns is to conceptualize them as "brain circulation," or a "triangular flow of human talent," by which high skilled migration is posited as benefiting both the emigrating and immigrating country, rather than benefiting only one at the expense of the other (Tung, 2008). In an interesting analysis from Defoort (2008), it was concluded that brain drain has increased through time (mostly from 1990 to 2000). Long-term migration of highly skilled workers 25 years of age and older from the Central American region into the six main receiving countries (United States, Canada, Australia, United Kingdom, Germany, and France) between 1975 and 2000 was the third highest globally and second in Latin America, just behind the Caribbean. Since 1975 the main destination of highly skilled emigration from Central America has been the United States of America, with 98.8% of total skilled emigration rates. Moreover, in the year 2000, four out of the seven countries in Central America rank as 9th (El Salvador 30.4%), 10th (Nicaragua 28.8%), 17th (Honduras 23.9%), and 18th (Guatemala 23.5%) in the countries with a population size between 2.5 and 20 million inhabitants with the highest brain drain. The analysis of Lozano and Gandini (2011) portrays these differences by analyzing data from 1990 to 2007 from these regions. The difference strives in how skilled migration in less populated or smaller countries such as Haiti, Dominican Republic (33.0%), Belize, Nicaragua, and Honduras (25.0%) appear higher than in highly populated and bigger (10.0% or less) countries like Brazil, Venezuela, Colombia, and Peru, just to name some. In specific reference to the Central American and Caribbean Region, including the case of Mexico, there is evidence that the highly skilled migration target is mainly the United States of America, Canada and Mexico, with Mexico as the country with the highest skilled migration rate of all Latin-American countries (increasing emigration rates 3.7 times from 1990 to 2007, 207%) (OIM, 2019). In terms of the educational level of the highly skilled migrants, data surprisingly showed that more skilled migrants born outside the United States of America have a doctorate compared to US citizens. This was not the case for those holding a bachelor's, where the opposite trend was evident. Furthermore, skilled migrants having a gainful job based on their qualifications in the United States was the following, according to their academic level: with a bachelor's degree 68.2% (at a higher disadvantage), master's degree 20.4% and a doctorate 11.4%. Likewise, a so-called "brain waste" refers to the underemployment of skilled migrants who work in occupations whose qualification requirements are below their education levels (Özden, 2005). In this sense, in all regions of the world, unemployment is higher among skilled immigrants as citizens [4.0 and 3.2% for those originally from Africa and Latin America (4.2% for Guatemala), respectively] (Lozano and Gandini, 2011). The literature describes the interaction between host countries and highly skilled migrants as a "massive phenomenon" in terms of the economic and human resources potential for both the target and origin countries. It is such that more countries have identified their potential and is now part of the strategic plan proposed by the OECD in their 2035 future assessment in skilled migration (OECD, 2020). Such tendencies and views are still not that positive for the Latin American and the Caribbean (LAC) region. For instance, demographic data retrieved from the United States of America (the main destination for highly skilled migrants in the LAC region) until 2011 indicates that the labor increment of highly skilled migrants is still lower than that of citizens with a higher tendency toward increased educational level. It is necessary to highlight that these data might not explicitly represent the perspective and view of all countries hosting the Guatemalan Scientific Diaspora (GSD). Thus, the presented outcome could explain a gap between national policies, perception, international relations, and the labor market.

Approaches to the Term Diaspora in the Context of Science

According to the International Organization for Migration (IOM), a diaspora has been defined as a general concept referring to ethnic persons or populations, individuals, and members of networks and organized associations who left their homelands of origin and maintained a connection with their countries (OIM, 2021). IOM emphasizes the transnational dimension of diasporas, the relation between their country of origin and destination, rather than the historical connotation. On the other hand, scientific diasporas (SD) have been defined as "self-organized communities of expatriate scientists and engineers working to develop their home country or region, mainly in science, technology, and education" (Barre et al., 2003, p. 15). For Tejada (2012), scientific diasporas are made up of emigrated scientists, and skilled professionals who have gained recognition as promoters of research and communicators of knowledge contributing to scientific, technological, and socio-economic development in their home countries. During the last decades, various countries have been developing policies to counteract the brain drain by attracting highly skilled people to their country of origin through incentive schemes without success. For Tejada et al. (2013), large-scale emigration by scientists and qualified professionals from developing and transition countries in search of better opportunities and career prospects in high-income industrialized countries, commonly known as "brain drain," is a significant concern for their respective home countries. Nonetheless, the emigrated human capital can also bridge the home and host countries, promoting the transfer of ideas, skills, and knowledge. Burns (2013) considers science diasporas as engines of innovation, as in the United States of America, a quarter of foreign-born workers with college degrees work as scientists or engineers. In Silicon Valley, California, 44.0% of these engineering and technology ventures were founded by at least one immigrant (Burns, 2013). This is consistent with Meyer (2007) and Tejada (2012), who identify the power of the scientific diaspora as a driver for development and improvement. The concept of scientific diasporas started to reference networks or organizations of emigrated scientists and engineers from developing countries living in industrialized countries (Barre et al., 2003). Such networks or organizations were thought to work together to "transfer knowledge to their countries of origin through diverse forms of cooperation from a distance" (Tejada, 2012, p. 61). Another relevant concept is diaspora knowledge networks (DKN). According to Meyer (2007), DKN provides new policy options in innovation, science and technology, migration and development, and international cooperation. Brown (2002) argues that scientists leave their home countries to study or work in an industrialized country to acquire knowledge and expertise they might not have gained if they remained at home. They also establish knowledge and information networks in the host country. For Meyer and Brown (1999), the rise of DNK during the 90s portrayed a potential resource for practical cooperation between developing and highly industrialized countries. For the last two decades, the conception about the migration of skills evolved from brain drain to brain gain (The National Science Technology Portal of the Republic of Belarus, 2020). Some countries, as in the case of Belarus, promote policies to discourage university graduate students from migrating, especially those who studied in a public university, as a result of certain repay dispositions to the Education Code in 2011, in which "graduates from state universities and specialized secondary educational institutions where the tuition for their study was paid by the state have to work for an employer assigned by the state for two years following graduation" (CASE, Kazmierkiewicz and Kulesa et al., 2021, p. 23). The stance of populist governments in the Global North in recent years has created a new paradigm in skilled migration. This new paradigm is called "brain rejection," which refers to the rejection of highly skilled migrants in traditional destination countries such as the United States or the United Kingdom. These countries have questioned the benefits of the brain gain strategy for developing the recipient country.

The reasoning behind "brain rejection" in populist narratives is protectionism of culture and the economy, especially when it comes to native workers (Tigau, 2020). Most of the literature has focused on the voluntary and economic migration of highly skilled migrants. However, some professionals flee their home countries due to conflicts and wars (Tigau, 2019). Refugees are not always poor and uneducated, but a good part of them are well-educated and successful people who migrate forcibly due to war circumstances (Tigau, 2019). A survey of 305 Syrian refugees in the UK, the Netherlands, and Austria shows that 38.0% have a university degree (Betts et al., 2017). Bang and Mitra (2013) find that ethnic civil wars significantly impact the magnitude of skilled migration, while non-ethnic wars do not have a strong and significant effect. Ethnic wars increase the number of high-skilled migrants by 5.0–8.0%, and each additional year of war increases the share of high-skilled migrants by 0.4–0.7% (Bang and Mitra, 2013). One of the main challenges of highly skilled refugees is finding a job due to lack of institutional support, language barrier, and assimilation obstacles (Betts et al., 2017). However, Tigau (2019) suggests that changing the perspective on refugees from burden to "boon" would allow professional refugees to be included in destination countries' brain gain strategy. In the same way, highly skilled refugees can be seen as potential positive contributors to conflict mitigation, de-escalation, and even resolution and post-conflict reconstruction in their home countries (Bercovitch, 2007; Koser, 2007; Bang and Mitra, 2013).

Experiences in the Scientific Diaspora in Latin America

In the case of Latin America, some countries have been adapting their policies regarding their diaspora to maximize the potential contribution to local development. In 2007, 94.0% of governments held policies and programs for their diaspora residing abroad, mainly in the United States of America (OIM, 2021). In the 1980s and 1990s, Mexican science experienced a period of expansion with the incorporation of researchers trained abroad, establishing the National System of Researchers to stop the flow of scientists abroad (Marmolejo-Leyva et al., 2015). The case of the Mexican Scientific Diaspora suggests that the mobility of Mexican researchers had a substantial impact on their production and the extent of their scientific collaboration. Some of them maintain their research engagement when they return. Marmolejo-Leyva et al. (2015) also found significant differences among areas of knowledge, where the most productive researchers are those in biological sciences, physics, and engineering. Indeed, the case of Mexico offers an interesting example in Latin America of the contribution of the scientific and technological development of their home country (Rivero and Trejo-Peña, 2020). A recent study by Marmolejo-Leyva et al. (2015) identified that a high number of scientific productions in collaboration with countries from the Global North, mainly the United States of America and the United Kingdom, was produced between 2003 and 2009. This occurred after high global migration rates register in between 1990 and 2007: the "stock" of highly skilled professionals with origins in Latin American and Caribbean countries increased 155.0%, followed just by Africa and Asia with 152.0 and 145.0%, respectively (Tejada and Bolay, 2005; OIM, 2019). The key to the collaboration of the Mexican Scientific Diaspora with their country of origin relies on the ties it still maintains with Mexican institutions. These have resulted from a few governmental return and repatriation policies, such as the National System of Researchers (SNI-for its acronym in Spanish) from the National Council for Science and Technology (CONACyT-for its acronym in Spanish) created in 1984 by a presidential decree recognizing the scientific career of researchers and providing economic stimuli. In 2003, the Institute of Mexicans living abroad was created, and in 2005, the Chamber of Deputies passed a law to support former Mexican migrant workers. Finally, some independent initiatives from non-governmental institutions have arisen, like the Red Global MX, which bridges relationships between highly skilled Mexicans and local institutions. There is still much to do regarding return policies, as many interviewed scientists highlighted that no real investment in science and technology exists; only superficial incentives are provided to scientists from the SNI system. Moreover, incipient repatriation programs are offered to highly skilled workers (Rivero and Trejo-Peña, 2020). Also, in Colombia, the Colombian Ministry of Science, Technology and Innovation (Miniciencias for its acronym in Spanish) promotes access to master's and doctoral programs abroad, nevertheless repatriation or engagement actions subsequent to their completion is very weak (Echeverría-King, 2021). In the case of Central America, diaspora organizations are often involved in activities focused on their country of origin. They range from small donations to investments and infrastructure projects and in the case of Guatemala 31%, organizations related to their diaspora carry out food support actions in favor of their communities of origin (OIM, 2021). The National Council for Attention to Migrants (CONAMIGUA) is among the organizations that provide attention, engagement, and participation with the diaspora, mapped by the IOM, which has a registry of irregular migrants that is not publicly accessible and does not include the GSD.

Notwithstanding, research on how the needs and perceptions of the scientific community (i.e., diasporas, returned scientists, and local peers) dialogue with stakeholders back in their home countries is lacking. To plan for any future policy engagement, this research aimed to outline the potential of the GSD network as a mechanism for building research excellence and intellectual capital while also delving into the existence and accumulation of the GSD and stages for their engagement with their country of origin. Furthermore, it aimed to address how technology might turn "brain drain" into "brain circulation" and enable the articulation of the GSD as a viable opportunity to generate collaboration between scientists abroad and local actors, ultimately impacting the building and development of the Guatemalan scientific capacities. This research sheds light on the current state of the mapping, characterization, and identification of the GSD for their engagement and interactions with their peers, relevant stakeholders, and broader sectors of the society back in their country of origin.

TABLE 1 | Criteria—selection of key respondents of semi-structured interviews scientific community.

Criteria	Description	Operationalization
Experience	Experience in community building or participation, networking, groups of scientists	Reporting experience in building and/or participating
Trajectory	Procure diversity in the representation of career development stages of the interviewees (early, mid-established career)	Years since completion of graduate studies. Early < 10 years, Mid +10 years but no management positions or group coordinators. Established +15 years in addition to management or research group coordination positions
Field of Expertise	Diverse fields of knowledge (i.e., natural sciences, health, earth science, social sciences, physics, engineering sciences)	All fields of knowledge were considered, including social, natural, and engineering sciences
Destination Diversity	Covering a wide range of geographic locations for destination	Including as many geographic destinations as possible region/country, i.e., North America, Europe, Asia, Latin America
Gender Balanced	Balanced participation of women and men	Gender equality in the participation

TABLE 2 | Perspectives and stakeholders relevant to the GSD.

Perspective	Profile of the stakeholder
Science technology and innovation policy	Institution/Organization relevant to the Science, Technology, and Innovation Policies in Guatemala, e.g. The Guatemala National Secretariat of Science and Technology SENACYT, the Secretariat for Planning and Programming of the Presidency SEGEPLAN, the Commissions of Science, Technology and Education in the National Congress, Association of the Agricultural Chemical Guild (Agrequima)
Foreign policy	Institution/Organization relevant to Guatemala's foreign policy. e.g., Ministry of Foreign Affairs, Central American Parliament, Commission on Migrants and Commission of International Affairs of the National Congress
International partner	Institution/Organization engaged in science and technology international cooperation with Guatemala, e.g., UNESCO, Foreign Missions accredited in Guatemala, the Central American Integration System SICA
Higher education/research institutions	Universities with full-time research positions/Public or Private Research Center, San Carlos of Guatemala University, Del Valle de Guatemala University, Rafael Landivar University, Mariano Galvez University, the Central American Council of Higher Education CSUCA
Industry/private sector	Organization/Firm from the private sector engaged in Research and Development Activities, i.e., Cementos Progreso (Cetec, research institute), Agexport (Network I+D+i), Cámara de la Industria (Industry Chamber), AGEXPORT, Cámara del Agro (Agribusiness Chamber) and CAB-Corpo, CNE GT (Consejo Nacional Empresarial)
Social/ civic organizations	Organizations from the organized Civil Society. e.g., Institute for the Development of Higher Education (INDESGUA), Fundación Desarrolla Guatemala to the acronym (FUNDEGUA), Demos2025, the Luis Vohn Ann Foundation

METHODOLOGY

The research was conducted using a qualitative methodology. Data was collected from two groups of participants: (i) The Scientific Community with emphasis on members of the GSD, and (ii) the perspective of a comprehensive group of Stakeholders with relevance to the GSD. To select the first group, a strict set of criteria was designed to guarantee a diversity of views and perspectives (**Table 1**).

In the case of the second group, a categorization of six perspectives was followed to include an integral approach (**Table 2**). The presented data was collected between September 2021 and February 2022.

As for the methods for data collection, participants were offered two alternatives (considering their time availability): (i) Semi-structured interviews and (ii) Participation in Focus Group Discussions. **Tables 3**, **4** present the profiles of the participant Scientists and the Stakeholders, respectively.

To fulfill the general objective of this study, literature review and desk research was carried out in complement to the collection of primary data. All interviews and focus group discussions recorded used different digital platforms and software (i.e., Google-meets, Zoom, and WhatsApp). Semi-structured interviews averaged 45 min, whereas focus group discussions averaged 60 min. A total of 30 h of audio-visual material were recorded. All materials were transcribed into text files (by listening and directly transcribing), codified, and analyzed to determine patterns, trends, shared content, and contrasting views. **Table 5** summarizes the criteria and sub-criteria used to analyze the data.

The study was reviewed and approved by the Ethics Committee at the University of Technology of El Salvador (UTEC). All participants were asked to sign an electronic informed consent form before participating in the study. Identities of participants are not identifiable nor traceable; all transcripts were encoded, and recorded material was shared only among members of the research team.

RESULTS

Mapping of the Guatemalan Scientific Diasporas

While mapping the GSD, two databases were identified and obtained. They were complemented with scientists of Guatemalan origin from different career trajectories both residing in Guatemala and abroad. Such information was

TABLE 3 | Participants from the Scientific Community: method, demographic distribution and fulfillment of the selection criteria.

Type of activity and demographic distribution	Participatory method employed	Participant selection criteria
Focus Group Discussion Total 18 **Gender**: Female 10; Male 8; other 0 **Field of expertise**: Biomedical sciences 2; Business and Innovation 1; Educational Sciences 1; Engineering and Computational Sciences 3; Environmental Sciences 7; Physics 1; Social and Political Sciences 3 **Geographical location**: Asia 2; Oceania (incl. Australia) 0; Central America 3; Europe 6; North America 4; South America 3 *Semi-structured interviews* Total 19 **Gender**: Female 12; Male 7; other 0 **Field of expertise**: Biomedical sciences 5; Business and Innovation 1; Educational Sciences 1; Engineering and Computational Sciences 5; Environmental Sciences 4; Physics 1; Social and Political Sciences 2 **Geographical location**: Asia 3; Oceania (incl. Australia) 1; Central America 1; Europe 7; North America 7; South America 0	*Online Focus Group Discussion* 6 focus groups with different numbers of participants fitting the criteria selection (Group [G] 1:5, G2:4, G3:2, G4:2, G5:3, G6:2). Average duration 60 min *Semi-structured interview* One-to-one interviews with an average duration of 45 min	*Trajectory* 1. early career 2. mid-career and 3. established career

TABLE 4 | Participants from the stakeholders: method, demographic distribution and fulfillment of the selection criteria.

Type of activity and demographic distribution	Participatory method employed	Participant selection criteria: perspective
Focus Group Discussion Total 26 (Female 11 Male 15) Gender: Female 12; Male 13; other 0 *Semi-structured interviews* Total 11 (Male 6 Female 5) Female 5; Male 7; other 0	*Online Focus Group Discussion* 6 focus groups with different numbers of participants fitting the criteria selection (G 1:4, G2:7, G3:3, G4:6, G5:3, G6:3). Average duration 60 min *Semi-structured interview* One-to-one interviews with an average duration of 45 min	*Perspective* 1. Science and technology policy 2. Foreign policy 3. International partner 4. Higher education/Research institutions 5. Industry/Private sector 6. Social/Civic organizations

publicly available. The two databases are from registered members of two networks of Guatemalan scientists: First, the International Network of Science, Technology and Innovation of Guatemala and second, the Organization of Women in Science from the Developing World-Guatemalan Chapter (OWSD-Guatemala). Demographic information gathered from these databases included: (a) gender (female, male), (b) last completed academic degree, (c) field of knowledge/expertise (i.e., natural sciences, social sciences, computer sciences, health, education, etc.), and (d) geographical location of their place of residence. Descriptive statistics were conducted to determine percentages, means, and standard deviations from the gathered data. The information available from the two databases summed up 631 scientists, out of which 78.0% (n = 491) are female. Seventy percent (n = 441) reported as country of residence Guatemala (female n = 392 and male n = 140) living in 33 countries, including Guatemala. In relation to their country of residency and work of the GSD, both North America (United States of America n = 58, Mexico n = 20 and Canada n = 3) and Europe (France and Germany both n = 14, Spain n = 13, United Kingdom n = 9, among the main) followed by Asia 1.1% (n = 7), Oceania 0.5% (incl. Australia n = 4) and no reports from countries in the African continent (**Figure 1**).

International Network of Science, Technology and Innovation of Guatemala—RedCTI

In 2005, the National Council of Science and Technology (CONCYT) brought together a group of Guatemalan scientists who worked on research activities and had their place of residence outside of the Guatemalan territory. This action aimed at "strengthening the science and technology capacities in Guatemala to ultimately propose solutions to the problems in the Guatemalan society"[1]. The meeting was called *Converciencia* and resulted in the foundation of the International Network of Science, Technology and Innovation of Guatemala (*RedCTI*) by signing a Constitutive Act during the event's closing ceremony. The *RedCTI* Network has been in operation since its creation (over 15 years) with the support of the National Secretariat of Science and Technology (SENACYT). The SENACYT is the coordinating public institution. It is responsible for supporting

[1]https://redcti.senacyt.gob.gt/portal/.

TABLE 5 | Topic criteria and sub-criteria for data analysis.

Topic	Criteria	Sub-criteria	Terminology coded (key words) in each sub-criterion	
Identification	Current situation		Not aware of databases/mapping, *Converciencia* (yearly scientific event in Guatemala) Red CTI (International Network of Guatemalan Scientists)	OWSD (Organization of Women in Science in Developing Countries) SENACYT (National Directorate of Science and Technology), Fulbright (United States of America scholarship program)
	Limitations and critique		Lack of: Interests/attention Linkage	Maturity Policies Data
	Proposals and technological potential		Related databases Social Networks to map (Facebook, LinkedIn, Research Gate)	Data mining
Connection	Current situation		Lack of experience No collaboration Mentoring activities	Scientific dissemination Collaboration in projects and scientific publications
	Limitations and critique		Lack of: Connection/linkage Interinstitutional coordination	Communication Normative Transparency
	Proposals and technological potential		Related social networks (Facebook, LinkedIn, ResearchGate) Communication technologies (Whatsapp, Zoom, Meet, BlueJeans, Slack)	Articles and publication platforms (Scopus, Academia) Database of scholarship holders Video platforms (TedEx, YouTube)
Engagement	Current situation	Diplomacy	Lack of programs from the Ministry of Foreign Affairs Embassies or Missions	Fulbright programs
		Governmental institutions	Strengthen programs and networks	Lack of political will
		Scientific communities, OWSD, Academia, Civil society	OWSD activities *Converciencia* activities Scholarship holder networks	INDESGUA (Higher education development institute, in Spanish) database
		Universities and Academies	Projects Exchange	Observatory Policies
		Industry	Industry Chamber Partnership	*Guatemaltecos ilustres* (Prestigious prize for recognized Guatemalan professionals)
	Limitations and critique	Diplomacy	Lack of: Incentives/rewards Coordination	Language Interest
		Governmental institutions	Lack of: Organization	Investment Policies
		Scientific communities, OWSD, Academia, Civil society	Lack of working tables with more sectors Lack of Involvement	
		Universities and Academies	Communication Infrastructure	Inter-institutional collaboration Trust
		Industry	Communication	
	Proposals and technological potential	Diplomacy	Communication	Will
		Governmental institutions	Communication	Identified needs
		Scientific communities, OWSD Organization of Women in Science for the Developing World, Academia, Civil society	Integration strategy	Dissemination
		Universities and Academies	Dissemination	
		Industry	Communication	

and implementing the decisions that emanate from the CONCYT (for its acronym in Spanish)[2].

[2]https://www.senacyt.gob.gt/.

The *RedCTI* was created to contribute to the preparation and implementation of scientific-technological development plans through science, technology, and innovation and propose viable alternative solutions to improve the population's quality of

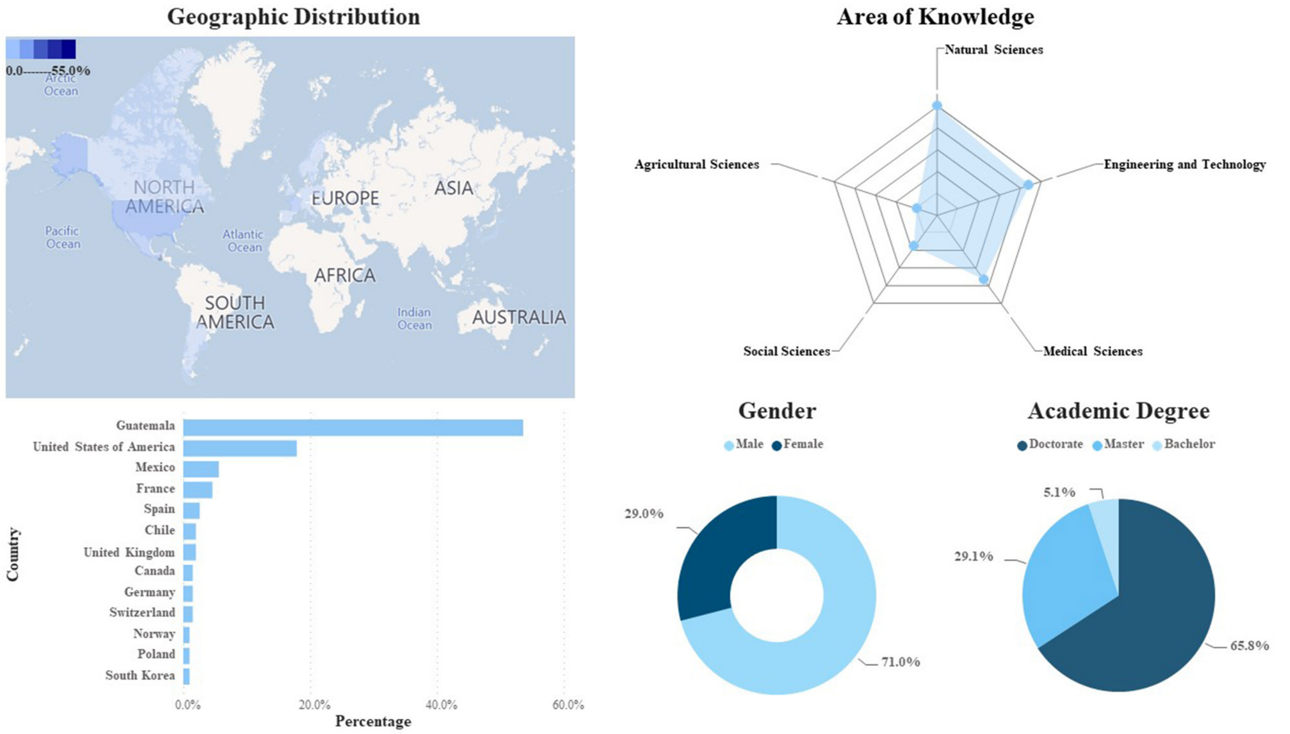

FIGURE 1 | Mapping of the GSD—based in two networks RedCTI/OWSD Guatemala.

life. Moreover, one of its main goals is to link Guatemalan scientists working outside with those inside the country. As of February 2022, this network registered a total of 196 members, according to the database provided by SENACYT. The directory allows mapping the GSD according to their gender, field of knowledge, and country of residence. Applying a binary gender filter (female/male) in this network, 71.4% ($n = 140$) are male and 28.6% female ($n = 56$). According to their field of knowledge professionals reported in this network includes 23.5 ($n = 46$) in the Medical Sciences 31.6% ($n = 62$) in the Natural Sciences, 27.6% ($n = 54$) in Engineering and Technology, 11.2% ($n = 22$) in Social Sciences, and 6.1 % ($n = 12$) in Agricultural Sciences. In terms of the level of education among its members, 5.1% ($n = 10$) reported having completed a bachelor's degree (*licentiate*), 29.1% ($n = 57$) master's degree, while 65.8% ($n = 129$) hold doctoral degrees (Ph.D.). Interesting data refers to the reported country of residence 53.6% ($n = 105$) reported their country of residence as Guatemala, while 46.2% ($n = 91$) reside abroad. In this aspect, a more comprehensive concentration of GSD is found in the United States of America with 17.9% ($n = 35$), followed by Mexico at 5.6% ($n = 11$) and 4.6% in France ($n = 9$). Other destinations with less presence include Argentina, Puerto Rico, Hungary, Italy, Netherlands, Sweden, Japan, and Taiwan (**Figure 2**).

The Organization of Women in Science for the Developing World Guatemala National Chapter

OWSD-Guatemala is a community of women scientists conforming to the national section of the global organization Women in Science for the Developing World (OWSD). This international organization was co-founded by UNESCO and the World Academy of Sciences TWAS in 1989 (OWSD, 2021). OWSD operates in four regions: 1. Africa, 2. The Arab Countries, 3. Asia-Pacific, and 4. Latin America and the Caribbean (LAC). OWSD-Guatemala, as a national section, belongs to the LAC region. To establish a national section (country-based), a minimum of 20 members must apply for international recognition supported by a local organization (Host Institution) with legal status and active operations. In the case of OWSD-Guatemala, the National Chapter is hosted by the Academy of Medical, Physical, and Natural Sciences (OWSD, 2020). As of February 2022, this network incorporated over 435 women scientists. The network's website allows the identification and location of members by name, area of expertise, year of membership, and OWSD awards or fellowships. From the available data, 77.2 % ($n = 336$) of its members indicated they have a residence in Guatemala. Of those reporting living abroad, 11.3% ($n = 49$) indicated living in European countries, while 7.4% ($n = 32$) in countries of North America. 2.1% ($n = 9$) reports living in South America, 0.7% ($n = 3$) in Asia and just 0.9% ($n = 4$) in Oceania (incl. Australia). With regards to their area of knowledge, the proportion of self-reported disciplines were: 27.0% ($n = 118$) in Agricultural, Biology, Earth Sciences (incl. Space Sciences and Astronomy) as well as for Interdisciplinary, Humanities, Social and Economic Sciences, respectively; 19.3% ($n = 84$) in Astrophysics, Physics, Math, Engineering, Computer Sciences, and Communication, 14.0% ($n = 61$) in Veterinary, Livestock and Health Sciences and

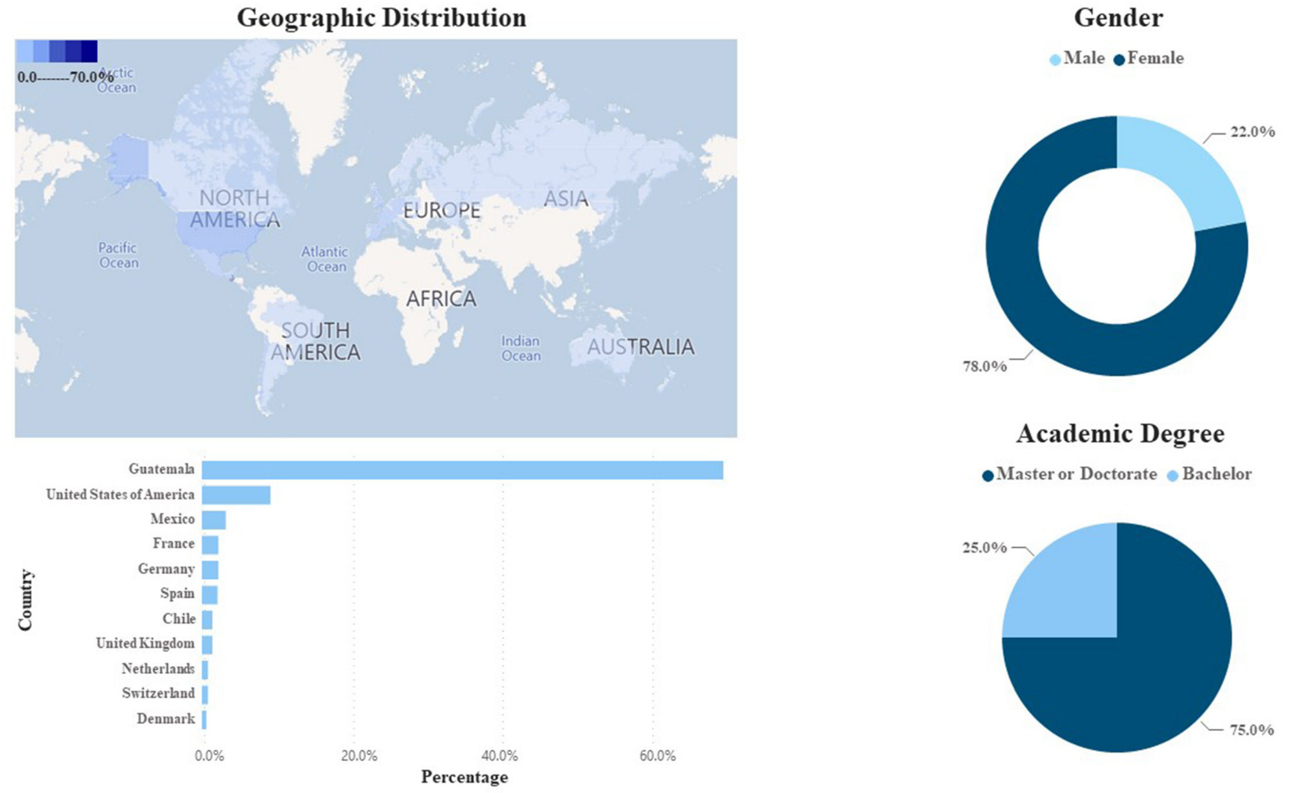

FIGURE 2 | Geographical, area of knowledge, gender, and academic degree distribution of the scientists of the international network of Guatemalan scientists RedCTI (February 2022).

12.0% ($n = 54$) in Chemistry and Food Sciences. In terms of the level of education, 34.8% ($n = 148$) hold academic degrees at the undergraduate level, while 66.0% ($n = 287$) hold academic degrees at the graduate level (master's or doctoral) (**Figure 3**).

Interaction Between the Scientific Diasporas and Stakeholders in Guatemala

Interactions between the GSD and different stakeholders seem to be erratic, episodic, and promoted with fragmented initiatives that ultimately obtain partial and inconsistent results. Moreover, as the engagement of the GSD with their country of origin is still unexplored to a significant extent, the roles and responsibilities among key stakeholders in their interaction with GSD is still a pending issue.

At the policy level, CONCYT is the governing structure in scientific and technological development in the country. It is responsible for the promotion and coordination of activities carried out by the National System of Science and Technology members. The Law for the Promotion of National Scientific and Technological Development (Congreso de la República de Guatemala, 1991) establishes that CONCYT is the country's highest decision-making and policy creation institution. This body coordinates entities relevant to Guatemala's science and technology areas, including those in the industry and academic sectors. In other words, CONCYT oversees national scientific and technological development. Nine members integrate this council; the Vice-President of Guatemala (who Chairs the CONCYT), the Minister of Economy, the President of the Science and Technology Commission in the Congress of Guatemala, the President of the Chamber of Industry, the President of the Chamber of Agribusiness, The President of the Chamber of Commerce, The Rector of San Carlos University (the public University), a representative on behalf of the rectors of all private universities and the President of the Academy of Medical, Physical and Natural Sciences of Guatemala. This council leads the country's national policies related to science and technology, but the functional part is delegated, by law, to SENACYT. As part of this study, the research team mobilized critical stakeholders from six perspectives: Science and technology policy, foreign policy, industry/private sector, civil society organizations, higher education, and international cooperation organizations (**Figure 4**).

DISCUSSION AND FINDINGS

To facilitate the discussion and in harmony with the design of the research instruments, three stages are laid out in this section, considering the process of engaging the GSD with their

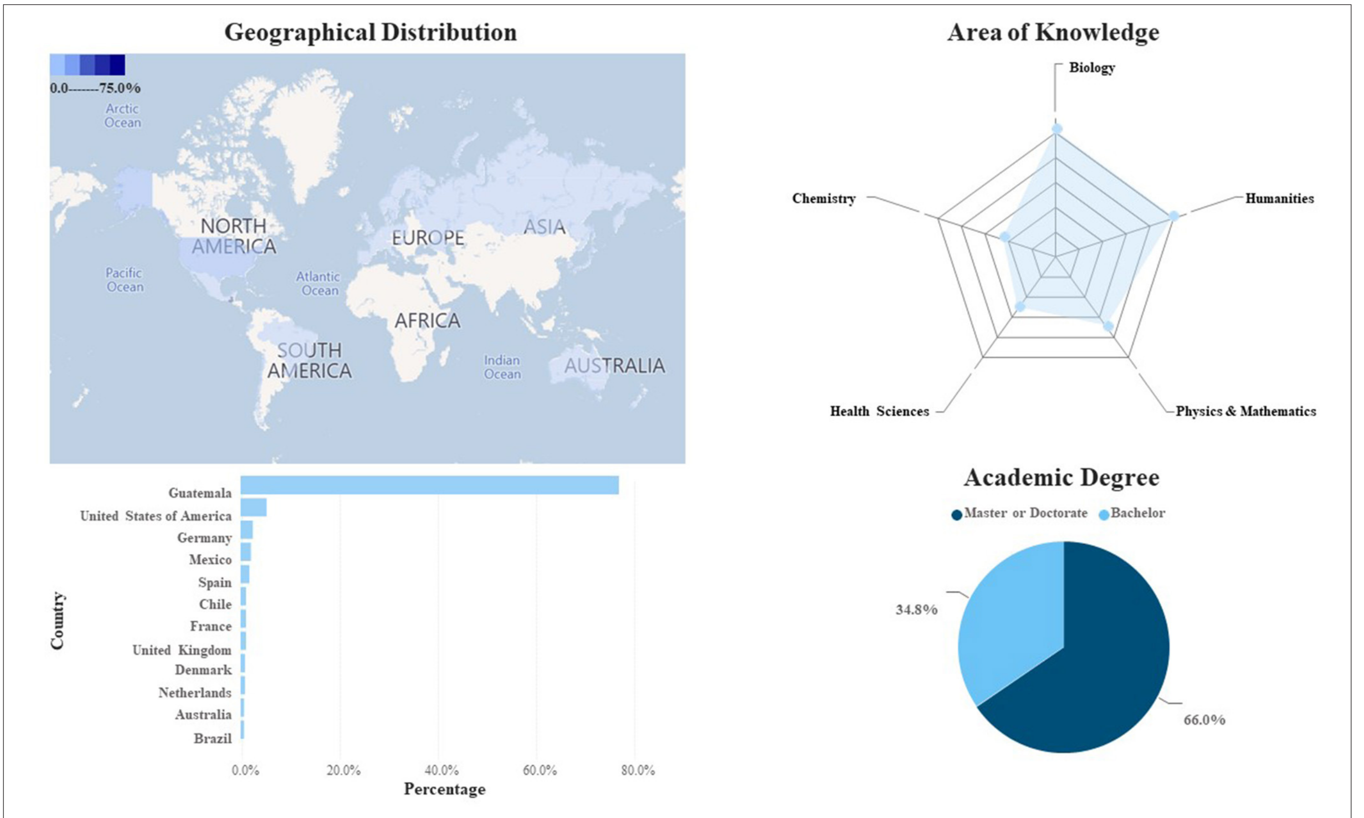

FIGURE 3 | Geographical distribution, area of knowledge, gender, and academic degree distribution of members of the Guatemala National Chapter of the Organization of Women in Science for the Developing World OWSD (February 2022).

country of origin. The first stage—Identification—involves the very existence of a GSD, the sense of belonging on behalf of the scientific community, while grasping the understanding of GSD from the key stakeholders. In this stage, it is critical to gain in-depth knowledge of the composition and characteristics of the GSD. The second stage -Connection—reflects the results obtained from the conversations between the GSD and their engagement in Guatemalan activities related to conferences, research projects, and others. The third stage -Engagement- is related to policy and sustained actions through which the GSD can effectively exert positive and constructive influence back on Guatemala. The participants in each stage identified barriers and obstacles and proposed recommendations and suggestions to overcome such challenges. The three stages are portrayed in the framework for the data analysis framework presented in **Table 6** and **Figure 5**.

Identification of the GSD

Scientific Community

Most of the participating scientists clearly understood the term *diaspora*; however, they pointed out that it was not commonly used in reference to Guatemalan general emigration and rarely apply to the relocation of Guatemalan researchers abroad. In addition, while some participants declared understanding the term *scientific diaspora* as "structured and organized groups of people interested in science who work and study abroad", others related the term to "unstructured, dispersed groups of scientists around the world". Participants indicated they clearly understood the concept *scientific diaspora* after searching for its meaning in dictionaries and expressed having identified themselves with the concept. The most common answer for the GSD interviewees on the reasons for migrating was the lack of academic opportunities in their scientific area of interest and the professional development barriers in Guatemala. Nearly all participants related scientific diasporas with brain drain.

Evidence collected in this study suggests diaspora is not a common term in the academic Guatemalan language. It was exposed that most Guatemalan scientists felt identified with the characteristics of the SD, thus they felt as part of the scientific diaspora from the focus groups. Nevertheless, many of the participants mentioned it was until recently learned the meaning of this term. The host institutions also expressed that it was a new term. A recent increase of conferences from Guatemalan scientists promoting this topic has created an effect on scientific diaspora awareness. For example, SENACYT in Guatemala has recently incorporated issues related to the importance of the scientific diaspora after promoting conferences and events[3].

[3]See https://blog.inasp.info/guatemala-scientific-diasporas/ and https://www.youtube.com/watch?v=0qSvnehuU4M.

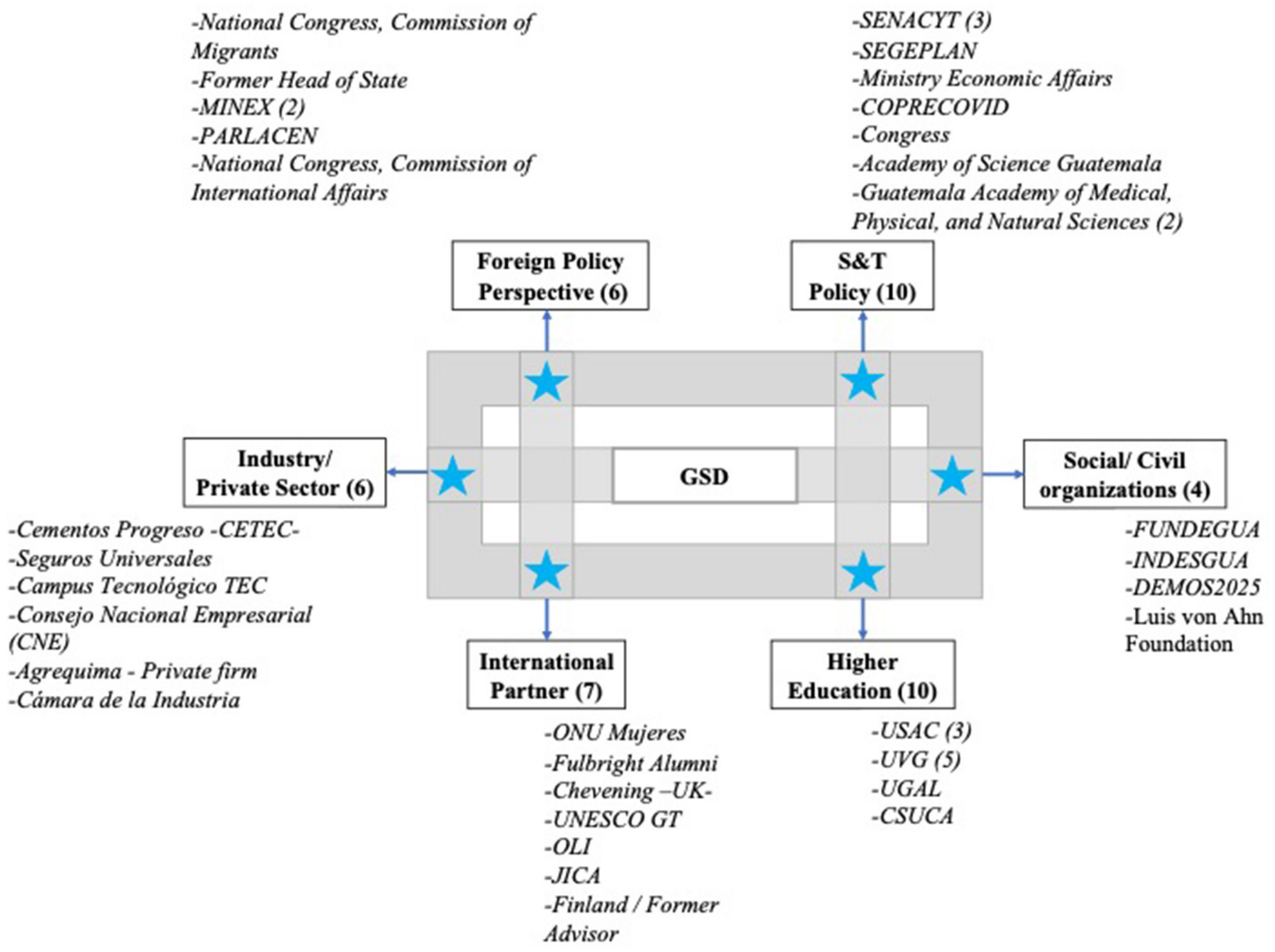

FIGURE 4 | Participant organizations representing the distinct sectoral stakeholders relevant for mapping the GSD (September–February 2022). S&T, Science and Technology; GSD, Guatemalan Scientific Diaspora; MINEX, Ministry of Foreign Affairs; PARLACEN, Central American Parliament; SENACYT, National Secretary of Science and Technology; SEGEPLAN, National Secretariat of Planning; COPRECOVID, National Commission for COVID19; TEC, Technology Campus; OLI, Online Learning Initiative; JICA, Japanese International Cooperation Agency; USAC, University of San Carlos of Guatemala; UVG, University Del Valle; UGAL, University Galileo; CSUCA, Secretary General of the Central American University Council; FUNDEGUA, Guatemala Foundation, INDESGUA, Institute for the Development of Higher Education in Guatemala.

Members of the GSD mentioned only three platforms to identify and map other Guatemalan scientists from the diaspora: the International Network of Science, Technology, and Innovation of Guatemala (RedCTI), the National Chapter for Guatemala of the Organization of Women in Science for the Developing World (OWSD-Guatemala), and the National Directory of Researchers -DNI- created by the Guatemala Nacional Secretariat of Science and Technology (SENACYT). The DNI is the most extensive database of researchers in the country; however, the GSD indicated they have heard about it in general terms, yet it does not include specific targets for Guatemalan scientists residing abroad. The DNI platform has filters, statistics, and promotion limitations to include more scientists living abroad. According to sustained communications with the technical personnel from SENACYT during the study, this platform will be improved through 2022. Changes include improving a more pleasant user experience, updating profiles, and promoting the site to increase the number of registered scientists.

Participants see an opportunity to build a robust platform using the technology and the data available in the existing platforms (RedCTI, OWSD-Guatemala, and DNI), similarly to experiences of other countries from the region and through the application of technological tools. For example, Costa Rica has a scientific diaspora mapping tool on the web with information about current location, plans of return to the government, reasons to leave the country, and collaborations opportunities[4]. Recent research (Loannidis et al., 2022) has shown that mapping and characterization of the scientist diaspora could be done using search engines and authorship directories in journals such as

[4]https://hipatia.cr.

TABLE 6 | Framework for data analysis—stages in engaging with the GSD.

Stage	Guiding questions	Means/mechanisms
Identification	What is a scientific diaspora? Who becomes a member of the Guatemalan Scientific Diasporas (GSD)? Where is the GSD located (countries of residence? In which fields of knowledge do the GSD members do research? Which characteristics (gender, level of education) do the GSD present?	Networking platforms Existing structured mechanisms (beyond social media groups) Systematic Group Participation
Connection	How do the members of the GSD interact among them? How do the members of the GSD interact with other stakeholders?	Social Networks (e.g., LinkedIn, ResearchGate), Alumni Associations (e.g., Association of Guatemala ex-Fulbright scholars, DAAD Alumni, KOICA Alumni) Individual initiatives (informal groups) Actions promoted by institutions organizations (e.g., INDESGUA—interactions among scholarship awardees, *Seguros Universales—Guatemaltecos Ilustres*)
Engagement	Which types of engagement have been experienced by the GSD? Which forms of engagement have proven effective/ineffective? What are the obstacles for the GSD engagement? Which solutions can be identified to overcome the obstacles to the GSD engagement with their country of origin?	Isolated Activities/Events Legislative actions Science and Technology Policy Foreign Policy Artificial Intelligence Machine Learning Policy and practice—institutions/organizations reached out to the GSD

Scopus. For this, a specific question from the instrument used in this study explored the possibility and potential of technology such as artificial intelligence (AI) and even machine learning to identify Guatemalan items and, thus, aid in mapping its diaspora. AI can remain a tool to produce valuable information that impulses essential public policies and government plans to integrate the GSD with their national counterparts. Among the obtained ideas, the possibility of mining data from Guatemalan scientists' articles for repositories could support the generation of monthly newsletters to engage the GSD, as already explored for the Greek Scientific Diaspora (Loannidis et al., 2022).

Some participants considered that through AI and machine learning, the process of developing algorithms and statistical models could be adapted to identify and analyze patterns in the GSD. Mainly as more researchers are familiar with social networks, informing systems with information about their country of origin, institutional affiliation, and fields of research. Conversely, various participants consider that AI or machine learning might not be applicable to identifying, mapping, and characterizing the GSD as this is not large enough to require such complex technology. In any case, participants agree that the current state of the GSD shows inefficient articulation, management, and identification of the potential of the GSD.

Key Stakeholders

Most stakeholders understand the concept of scientific diaspora. They frequently refer to it as a loss for the emigrating country caused by poor conditions in the emigrating country regarding resources, technology, education, and political and economic stability. For example, civil society stakeholders reflected on the loss of connection between the diaspora and their home country. However, stakeholders in the industry expressed their understanding of the diaspora with a positive sentiment, highlighting how it represents new opportunities for migrating scientists and new opportunities for collaborations between the industry and the GSD. While still understanding the concept of diaspora as a loss in human capital, stakeholders representing international partners also expressed it as a possibility to strengthen Guatemalan systems, as one of them shared: "I thought of seeds that sprout for science or the beginning of strengthening a system." Stakeholders representing the Science and Technology (S&T) policy sector pointed out that the definition of diaspora implies elements of organization and similar objectives, which does not characterize the GSD now. Notably, stakeholders representing Foreign Policy institutions were not entirely familiar with the concept of scientific diasporas.

In general, stakeholders indicated a lack of structured actions focused on mapping the GSD. Still, most could identify entities with the potential (and, perhaps, the responsibility). Stakeholders representing international partners expressed a keen interest in mapping the GSD and understanding the landscape regarding scientific development in Guatemala. An initial report about scientific development in Guatemala was published by UNESCO titled "Survey of research and innovation in the Republic of Guatemala" (Lemarchand, 2017), which is currently being updated in collaboration with SENACYT. Still, SENACYT, CONCYT, and Red CTI were named the existing networks with an untapped potential to map the Guatemalan diaspora. Representatives of higher education also see potential in the involvement of embassies. In general, OWSD was mentioned by most stakeholders as a network that is making a significant effort to collect data about women in the GSD and engage them in relevant topics of education and development in Guatemala. Notably, stakeholders in foreign policy institutions were unaware of any association or network to identify the GSD.

Stakeholders also identified examples of other functioning networks that have either successfully mapped a specific part of the GSD or could be used as a model for future efforts to map the GSD. Within these, alumni networks were often mentioned. Stakeholders in S&T indicated that alumni associations such as Taiwan and South Korea are perfect examples of strong networks. International partners also said the Chevening scholarship Alumni as a strong network with many members of the GSD. In relation to this, higher education representatives pointed out that communication between local scientists and scientists abroad is usually personal and based on personal interest or personal motivation. In line with this, they also identified the need for three essential elements to determine the GSD: "have people registered... then have them organized [through] an organization that allows them to interact, and finally institutionalization is needed, [meaning] someone who is in charge to follow up". Representatives of higher education also seem to have a bigger picture of the importance of identifying human capital for the development of Guatemala. One of them mentioned, "we [Guatemalans] not only have the potential of Guatemalans abroad but also of scientists who are in foreign universities and whose field of work is Guatemala, which is a very great potential."

Most stakeholders agreed that mapping the scientific diaspora is necessary and that a significant limitation in achieving this is the lack of a centralized effort to collect such information. Though most acknowledged the potential of AI to map the diaspora, few suggestions were made regarding its specific applications. International partners, for example, questioned what exactly would be considered AI while suggesting data mining to match publications, author names, and their countries to build a database of Guatemalan researchers and their work. Representatives of higher education identified the databases from *GuateFuturo* and SEGEPLAN as essential sources to identify the GSD while suggesting that the use of AI should be left for later. That initial effort should focus on constructing robust databases—an idea also shared by stakeholders in S&T.

Connection With the GSD

The National Development Plan, *K'atun*, Our Guatemala 2032 (Conadur/Segeplan, 2014) includes Guatemala's section in the international development agenda. This plan delimitates the need for Guatemala to redesign its development model, promoting bilateral, regional, and multilateral relations to adapt to the demanding challenges of a changing world. Emphasis is placed on the interactions between Government, civil society, and international partners, which should intensify and diversify to establish clear roles and responsibilities for each actor to contribute to the development of Guatemala. This certainly includes a mature and consistent foreign policy. The plan, however, does not have any concrete reference to policy or actions to facilitate the engagement with the GSD. It only mentions efforts to reduce poverty and irregular (low-skilled and vulnerable) migration; the plan does not address the high-skilled migration. As for the state of science and technology in Guatemala, a general section is included in the document describing the precariousness of these sectors in terms of investment and capacity building (Conadur/Segeplan, 2014). Yet again, no explicit mention of the GSD is found. The General Government Policy 2020–2024 (SEGEPLAN, 2020) presented in the Planning and Programming Secretariat of the Presidency, SEGEPLAN, includes a chapter about migrants, remittances and human rights protection. The *K'atun* Plan does not provide additional information about GSD or actions to reduce the brain drain.

Scientific Diaspora

In general, the GSD expresses its willingness to contribute to the country's development; however, several members of the GSD still feel disconnected from Guatemala. Many factors influence this feeling. One that prevails is the lack of intentionality and action by governmental authorities. The lack of a governmental strategy, structured cooperation/interaction mechanisms, nor an intentional approach to the Guatemalan scientists is finely expressed by one scientist:

> *And at the national level, it is difficult to engage because your very own Nation does not contact you to know where you are or what you are doing [...]. We have the knowledge and the desire to contribute to the country, but we don't see where, if we don't look, we make the effort to see where, right, if the government itself doesn't contact us, it's not interested, it doesn't know we exist.*
> -Member of the GSD

The SENACYT was the most frequently mentioned institution to connect the GSD with Guatemala regarding governmental responsibility. In this respect, it is relevant to acknowledge that this institution was created as an executive body to implement the STI public policies emanated from the CONCYT. With the current governing structure of S&T in Guatemala, CONCYT is the body in charge of designing and issuing policy guidelines in these sectors, while SENACYT merely implements such policies. In this sense, SENACYT officers participating in this study acknowledge the institution's role as a significant stakeholder; however, they call attention to the limitations. Particularly regarding budget allocation, which is low and undermines SENACYT's capacities to achieve its objectives, the trends in the financial resources allocated to the institutions have suffered steady reductions. SENACYT reports 59 employees as permanent staff, while 23 provide services holding temporary employment (SENACYT, 2022), which in addition to the budget limits (<US$5 million a year), negatively affects its capacities (MINFIN, 2021).

Besides governmental support, the primary barriers connected with the GSD include (a) The lack of doctorate programs in the country, which prevents more robust platforms from linking with local researchers. Moreover, social and economic scientists consider it essential to highlight the financial contributions of science to connect with government stakeholders and the population. (b) Lack of time was a barrier linking side projects in Guatemala or participating in existing networks. One of the participants mentioned, "Carrying out research takes a long time in collaboration, 5–6 years". (c) The lack of funds incentivizes locals to connect with the GSD and academic institutions, where teaching has more weight than research.

The members of the GSD suggested the use of existing technology platforms to connect with different projects and locals in Guatemala. Most mentioned platforms were WhatsApp®, email, video conferencing platforms such as Google Meets, Microsoft Teams, Zoom, Blue Jeans; social networking platforms such as private groups and public αMeta (Facebook) pages. They mentioned that using the existing ones could prevent social media exhaustion. Some others proposed the creation of new platforms that could allow for "posting" projects/interests, so the GSD can easily connect and identify opportunities for collaboration with other Guatemalan scientists, professionals, and other national authorities. Using AI algorithms, data can be mined, joined, and categorized to identify matching interests and demand of skills.

Key Stakeholders

Stakeholders are aware of numerous initiatives in the academic and scientific communities that promote and enable collaboration with scientists of the GSD. They acknowledged that it is mostly by individual researchers' motivation and through their personal and professional network that a large part of the existing collaborations is created. The strengthening of existing institutional networks was strongly recommended to promote working relationships between scientific communities and the GSD. Likewise, some specific scholarship programs, such as the German and UK Academic Exchange Service (DAAD and Chevening, respectively), were named influential in providing scholarships for higher education and maintaining strong ties and ongoing communications with its recipients.

Technology was mentioned as a valuable tool to facilitate communication and exchange between both parties. For example, using Zoom, Google Meets, or YouTube to host conferences and talks where researchers can present their work and highlight opportunities for collaboration. ResearchGate, Academia, LinkedIn, Twitter, and Facebook groups were also recommended as a tool that allows researchers to meet one another and share their profiles and expertise. However, some stakeholders expressed concern over the excess of existing social and professional platforms and proposed that a new platform would require powerful incentives for scientists to join.

Additionally, many thought it was critical to involve institutions such as CONCYT, SENACYT, and professional associations to make it easier to establish such connections and offer opportunities such as scholarships, research funding, and workshops for specialized training. Representatives of higher education identified some opportunities for improvement in CONCYT. They concluded that CONCYT needs to "keep a record, be active, have more budget, be more linked to GSD and include social sciences in its agenda."

Interestingly, there are already some organized efforts between stakeholders and the GSD. Stakeholders in Civil Society indicated they already hold strong ties with the GSD, particularly involving scientific collaboration and support to students aspiring to receive specific scholarships or study in a foreign country. International partners also mentioned collaborating with the GSD, specifically on topics regarding education. They also expressed the desire to further support women in the GSD, noting a disparity in their available opportunities.

Representatives from different groups in society also identified some barriers to connecting the GSD with local scientific communities. Stakeholders in S&T policy mentioned that one of the significant challenges is the lack of interest of the GSD in working in the country. A participant noted, "Many of those scientists who live, and work abroad consider their condition of skilled emigrants as an achievement, [they] do not look back, they see escaping from their country as an opportunity in their career development. They are no longer interested in what happens back in their country; they may be working on a fascinating topic. Still, suppose they are asked to take part in collaborations. In that case, they disregard the invitations". This sentiment was echoed by stakeholders in Civil Society, who mentioned that, once students' goal of moving abroad was achieved, they showed little interest in keeping in contact and little commitment to being involved in supporting projects in Guatemala.

Moreover, one of the higher education representatives said that "the main barrier that I see is mistrust and the few spaces for advocacy with the public sector"; there are many difficulties connecting with decision-makers and promoting initiatives. It is generally complicated for scientists to be heard in political spheres. One of them mentioned that connecting the GSD to the political sphere is very "ambitious," yet believes that something more feasible is strengthening the GSD's connection with academic institutions to achieve better doctoral programs and research projects.

Engagement of the GSD (Actions/Policies)

Scientific Community

The stage of Engagement refers to a systematic, constant, and sustained participation of the GSD in different schemes, mechanisms, actions, and policies through which they exert influence in their country of origin.

> *Development must be driven by both the public [sector] and the private [sector]. A national policy to engage the GSD is necessary.* Member of the GSD
>
> *The biggest problem is that at the national level, there is no policy to include scientists in the development process of our home country.* Member of the GSD

Regarding the actions developed by the Ministry of Foreign Affairs, the GSD has not identified any program that links diaspora scientists with the country, and even when the scientists have suggested collaboration options, they have not received any formal response. The GSD stated that some embassies are helpful for students who study abroad. The embassy of the United States of America in Guatemala and the embassy of the United Kingdom in Guatemala were identified as some of the most dynamic connections with their alumni. These connections might be more systematic as they offer prestigious and globally recognized scholarships such as the Fulbright and Chevening programs. The GSD also pointed out that another limitation is the lack of diplomatic missions in certain countries such as Hungary and Switzerland. Whereas, having a Guatemalan embassy near them, such as the case of the Guatemalan embassy in Korea, might provide more support and resources. Many other members of the scientific diaspora point out that the inefficiency in general bureaucratic processes translates into the inefficiency of the embassies in connecting with the GSD.

Regarding the interactions with the government, the GSD generally showed dissatisfaction with the work of government institutions for linking them with projects in Guatemala. They indicated that the government should be more intentional and proactive in contacting Guatemalan scientists abroad since the GSD ".... has the knowledge and desire to contribute to the country, but there are no clear ways to do it". The GSD indicated that the meetings held by these institutions are fruitless because no concrete conclusions have been reached. It was also mentioned that the Red CTI is not agile. The research of institutions such as the Institute for Nutrition of Central America and Panama (INCAP) is not transferred to decision-makers. The GSD proposes that scientists get involved in the science and technology committees of the Guatemalan Congress. The GSD identified the importance of linking with the Ministry of Economy with structured conferences developed in Guatemala to involve more scientists. One of the actions suggested to get more involvement from the public sector is to measure indicators of the current situation in the country to assess the importance of making science-based decisions. Suggestions are used to strengthen the link between the Ministry of Economy and CONCYT, showing the economic relevance of science in the country to gain more confidence in the industrial sector with academia. The diaspora thinks that SENACYT has developed good outreach work, especially promoting STEM careers for girls. Among the limitations observed in the existing programs is the bureaucracy of the administrative system, i.e., for obtaining and managing funds, within the Red CTI meetings and decision-making without interaction with members, and lack of financial support for both research grants and follow-up of research activities.

They also mentioned the importance of *Converciencia.* This event in the past has provided opportunities for the GSD to connect with peers (period 2005–2020). The initiatives of the OWSD Guatemala chapter (period 2020–2021) have also been mentioned as crucial examples of how to link the diaspora and generate results and actions. Universities and industries have approached the diaspora collaborations by having them in conferences that have allowed them to connect and outreach to the Guatemalan audience.

Regarding the barriers to linking actions, scientists consider the lack of trust to give preference to their interests by the different sectors, the weak link between the academic and public sectors, the lack of public investment in research, development, and innovation, and the low value of science reflected in the workload and working conditions of most scientists residing in the country. A few scientists consider that top-down changes are complex and must be motivated from the bottom up, starting with transforming students' lives by researching and producing results that allow them to demonstrate the importance of science to the daily lives of the general population. One of the solutions AI could generate to support the actions for the GSD connections is to create a Guatemalan platform for the community of scientists. They proposed a tool that visualizes scientists' profiles and connects them directly with private institutions, government, or civil sector organizations interested in their academic contribution and professional skills.

Figure 5 summarizes the barriers and solutions identified by the Scientific Community, in the three stages.

Key Stakeholders

Stakeholders described current ties with the GSD as insufficient and weak. For example, stakeholders in the industry mentioned having some relations with the GSD but acknowledged these ties are weak and limited. Higher Education critiqued the approach of *Converciencia*, which members of the GSD identified as a valuable opportunity for connection. According to stakeholders in Higher Education, *Converciencia* was identified as a relevant mechanism for developing collaborations with the GSD. However, it shows at least two limitations (1) bringing scientists (including members of the GSD) who want to implement projects that do not correspond to the national context and (2) bringing scientists (including members of the GSD) who have prejudices about the knowledge of local scientists.

When identifying the reason for the current lack of collaborations, stakeholders underlined a lack of structure as one crucial obstacle to engaging the GSD in Guatemala's sustainable development. Stakeholders expressed that there is a lack of institutional systems and policies that enable the engagement of the GSD in the country's development. Only a few stakeholders had any knowledge about actions by the Ministry of Foreign Affairs and diplomatic corps in supporting such collaboration, which was described as insufficient and sporadic, even though both were considered relevant agents. Namely, the Department of State and the UK embassy were explicitly identified as entities that offer or have offered support to establish collaboration networks with the GSD. Likewise, stakeholders considered that there had been little action involving the GSD in topics of development and policymaking and a lack of interest and investment in science overall. SENACYT was mentioned as one of the most active government institutions because it finances the salaries of former members of the GSD who return to the country, involves GSD members in their activities, and has its Red CTI network. CONCYT was also mentioned as a relevant actor, although the result of its actions was deemed unsatisfactory. Finally, stakeholders representing Foreign Policy institutions considered that the Central American Parliament (PARLACEN) has the potential to generate regional impact in establishing such connections. However, its only action in this area is the creation of a regional fund for science and technology, which is currently being developed. The involvement of scientific experts in the development of industry was acknowledged as necessary. Still, none of the participating stakeholders had any knowledge of specific mechanisms that enabled the involvement of the GSD. It was generally agreed that universities and individual researchers

Category		Barrier	Solution / Solutions
1. Identification	1.1	• Unidentified members of the GSD abroad.	• Creation of an updated GSD database to later feed an AI identification model. • Development of GSD academic/networking events.
	1.2	• No digital profiling amongst some Guatemalan scientists.	• Raise awareness of digital connectivity to allow traceability • Create and increase digital profiling of GS.
2. Connection	2.1	• Lack of a connecting strategy from the Ministry of Foreign Affairs between the GSD with their home county.	• Scholarship-based networks (i.e. Fulbright and Chevening) are mentioned as functioning structures to identify and connect the GSD and which could be imitated by the Ministry.
	2.2	• Lack of Guatemalan Embassies in many of the residing countries of the GSD and on those existing these are weak (i.e. retrieval of contact information and failing follow-up meetings).	• Guatemalan embassies should contact Guatemalans also in neighboring countries who lack an embassy. They should also facilitate consular processes so that scientists continue their responsibilities abroad.
	2.3	• The bureaucracy of academic institutions in Guatemala often limits the GSD to academically advising scholars at local universities. Furthermore, this bureaucracy limits the execution of foreign funds in local universities.	• The GSD should link the current foreign university in which they are studying/working with local universities in Guatemala through internships for Guatemalan students. • Even when it is difficult, the GSD should keep trying to find spaces to train people in topics that are still underdeveloped in Guatemala and Central America. For instance, through National Aeronautics and Space Administration, Africa Flores has trained Guatemalans and Central Americans in remote sensing, coverage analysis, and water quality from a sustainable development perspective.
	2.4	• There is no systematic way to connect scientists other than social media.	• The GSD should look for membership in associations of scientists in the same field or alumni associations. • Create a platform with the databases of scientists and in some way that they can also interact with each other. • Use of existing social media such as Facebook, Twitter, LinkedIn, Google Scholar, and ResearchGate.
	2.5	• The academy in Guatemala is more focused on teaching than on research.	• The GSD should advise on research techniques so that projects of interest have higher academic rigor and therefore more efficient results.
3. Engagement	3.1	• Government institutions do not intentionally reach out to the GSD.	• Be proactive to approach the networks offered by government institutions and be part of them. • Actively look for spaces that are focused on influencing public policy such as initiatives led by the Universidad del Valle de Guatemala or the consortium of local universities. • Partner with the National General Directorate of the public university of Guatemala – Universidad de San Carlos de Guatemala.
	3.2	• The GSD's contributions to the creation of public policies are extremely limited.	• Identify local highly credible organizations dedicated to creating scientifically-based public policy proposals and link them with the GSD. In this way, both parties can create new consultancy venues: recruit students who are writing their thesis on a topic of public policy interest and train them to create a deliverable that can be sent for consideration by government institutions and at the same time meet their graduation requirement.
	3.3	• Academic publications are exclusive to the academic world and do not reach the Guatemalan population.	• Share information produced for academic articles on blogs to be more accessible to findings, solutions, and conclusions of topics of interest.
	3.4	• The GSD does not participate in any of the few networks that connect Guatemalan scientists due to a lack of time or shared interests.	• Participating in local networks will allow the GSD to apply for grants that require a team of scientists from the Global South.
	3.5	• Lack of funding opportunities to carry out research projects in Guatemala.	• Create a portal where scientists can find opportunities such as grants for research. • The GSD should look for grants that encourage developing projects in the Global South to apply in Guatemala. This can be part of any graduation requirement such as a doctoral dissertation or academic advancement such as the generation of academic articles. • The GSD should also train/mentor locals in grant writing, so more funds are available for local projects.

FIGURE 5 | Guatemalan Scientific Diaspora (GSD) - Barriers and solutions identified by members of the GSD (September 2019-February 2020).

	ROLES	ACTIONS
S&T Policy	Take actions to identify, map and characterize the GSD. Connect and engage its members with research grant opportunities and collaborations with the local context. Enhance interactions of the GSD with government institutions, industry and private firms, and wider sectors of the society. Negotiate the national budget for science and technology research.	Few links between S&T Policy actors and the FSD can be found. The most prominent has been *Converciencia*. Further actions could be taken as de GSD reports feeling neglected and unattended.
Foreign Policy	Issue and implement specific guidelines and policy measures to connect skilled emigrants (the GSD) with their country of origin. Promote academic, cultural and social exchanges among the GSD members in their country of destination.	The Guatemalan Diplomatic Missions accredited in foreign countries going beyond administrative purposes and consular services to the GSD. Include them in cultural activities, gathering Guatemalan university students / scholars / scientists living abroad.
International Partners	Support projects that address societal problems untapping the potential of the GSD members. Connecting and engaging GSD with local efforts led by the global community, through diplomatic means, technical and scientific exchanges; providing financial support for workshops, conferences, research, investments.	Promotion of science diplomacy literacy within the foreign policy institutions. Engaging alumni from partner countries scholarship programs managed by their diplomatic missions accredited in Guatemala. Supporting research, studies and projects related to the GSD.
Higher Education-Research Institutes	Channeling knowledge, skills and contacts of their alumni who have relocated abroad and their country of origin through their alma mater in Guatemala. Engage the GSD with Guatemalan research centers, universities and academia. Promoting mobility and other collaborations including students, scholars and researchers with the GSD.	Engage returned or GSD in distance postgraduate teaching or research positions. Advocate for more research funding. Capacity building and reducing the knowledge/capacity gaps between local and international institutions, using the contributions of the GSD .
S&T Industry / Productive Sector	Promote further efforts in R&D, engaging the GSD in such activities. Linking the GSD with the local Chambers of Commerce, Industry, Agribusiness, Construction and private firms. Participating in multi stakeholder efforts to engage the GSD.	Actions from private firms related to the GSD were not identified. An ongoing program Guatefuturo was referred to as a suitable example for this purpose. GSD indicated disconnection with the industry in Guatemala, Chambers seems to work in isolation, the most active and known Chamber among the GSD was the Chamber of Industry participating in the STI system.
Organized Civil Society	OCS can the GSD with wider sectors of the society and enhance their contributions to address societal problems. OCS can also advocate for policies aimed at using science, technology, innovation and research to address social problems.	GSD indicated that OCS frequently have acted in the absence of S&T and Foreign Policy actions. However they lack the financial/infrastructure resources. Coordinated efforts are required as GDS have filled vacuums left from the public institutions .

FIGURE 6 | Stakeholders—roles and actions identified by participants in engaging the GSD (September 2019-February 2020).

are the main drivers of scientific collaboration with the GSD, using their personal and professional contacts to establish networks and develop projects.

A second significant obstacle to engaging the GSD in Guatemala's sustainable development was a lack of sufficient resources and incentives. For example, representatives of Higher Education identified two main barriers to connecting the GSD with local scientists: lack of time and lack of funding. It was mainly acknowledged that the scientific community deals with various limitations (e.g., time, resources, bureaucracy, and career demands) that hinder the support they can potentially provide. Furthermore, stakeholders in Civil Society observe a lack of institutional support for research and scientific development in Guatemala, which has resulted in a lack of opportunities and incentives for the GSD to be involved in actions for development in Guatemala, either by returning to the country or collaborating from abroad. This effect was perceived by industry stakeholders as a lack of interest from the GSD to be involved in projects in Guatemala and a tendency to "forget" about their home country. As one member said, "We have [a relationship with the GSD], but it isn't stronger because some of them have forgotten about Guatemala." However, they acknowledged giving more support and incentivizing scientific development.

Stakeholders broadly commented on how the development of solutions should involve conjunct work between the public sector, private sector, and academia. However, some expressed concern over the lack of interest of government agencies in science and indicated that academia has the most substantial potential to lead the way in developing opportunities to involve the GSD in development projects. Still, all stakeholders could identify opportunities in which collaboration with the GSD would be fruitful. Particularly, stakeholders in S&T highlighted the importance of linking the GSD with the academic sector and the private and public sectors to develop such opportunities. In this way, the transfer of knowledge and technology could specifically target problems in Guatemalan society. Further, industry stakeholders reiterated their willingness to explore possibilities for collaboration with members of the GSD.

Regarding possible actions to overcome current obstacles, the need for more communication was highlighted. Industry stakeholders suggested having more open communication of industry needs to help identify opportunities for collaboration. Likewise, they underscored the importance of scientists showcasing their work and communicating their findings in a understandably and attractively way to the industry sector. One S&T stakeholder pointed out that multiple cultural barriers must be surpassed within the Guatemalan context, which requires contextualization and translation of scientific information.

Stakeholders also considered that governmental institutions need to be active in involving the GSD and that science policy needs to be developed—especially by linking it to economic policy and development to add incentives. Stakeholders in the S&T policy indicated that better inter-institutional organizations could create the connection of the GSD with projects in Guatemala. For example, they mention the communication between SEGEPLAN and SENACYT, where SEGEPLAN (in charge of administering international cooperation in the form of scholarships/fellowships) should systematically communicate the names and detailed information scholarship/fellowships awardees, especially at the graduate level (masters, doctoral programs). Then SENACYT can approach and connect them. Participants also mentioned the relevance of science diplomacy (as the interface between science and foreign policy) by suggesting that "the "SENACYT's policy and actions combined with the Ministry of Foreign Affairs [should engage] the GSD [by] having a scientific *attaché* in [Guatemalan] embassies and consulates, [and also] to train MINEX [Ministry of Foreign Affairs] staff and other public officials in science diplomacy guidelines." Some of them also recommended having at least a minimum plan of things that scientists could contribute; in this way, they would guide them on how to apply their knowledge in the country. **Figure 6** summarizes the roles and actions identified by stakeholders in engaging the GSD.

CONCLUSIONS

To our knowledge, this study is the first to provide supportive evidence of the growing and existing community of scientists outside of Guatemala, namely the Guatemalan Scientific Diaspora (GSD). Members of such GSD shared their past experiences, attempts, and results of their efforts for engagement with Guatemala and their current interest in contributing to the country's development through specific actions that need to be coordinated between the distinct sectors: government, academia, and industry. The importance of mapping, characterizing, and understanding the GSD to have a strong capacity-building mechanism and networking between GSD and local actors also became apparent. Until today, the existence of a GSD has not been systematically identified, registered, or studied and remains an untapped resource for development in the country. Moreover, the GSD has made positive initiatives and efforts, although they lack a legal or operational framework. As an initial step, systematized baseline information is required to develop further the actions toward structuring the GSD, develop future policies aimed to engage them, and highlight their impact at multiple levels of the country of origin.

This study highlighted the lack of knowledge of the existence of a GSD, their interaction with their national counterparts and local stakeholders, and the need to recognize it and develop a structure or plan for them to interact efficiently with Guatemala. Due to the lack of articulation, independent and few successful experiences were shared by the participants of this study, though they recognized the potential to develop more substantial collaborations.

Numerous members of the scientific diaspora have also acknowledged their responsibility to seek opportunities to remain relevant and positively influence Guatemala. Although the ideal scenario would involve an organized and systematized collective action, individual initiatives are also valuable. A sense of responsibility was also repeatedly mentioned, as many GSDs have benefited from scholarships, fellowships, grants, and funding based on their nationality or country of origin.

In turn, our participants sensed a more positive view of the GSD and the perception of the host country. Based on our results, the continuation of collaboration with and employment of Guatemalan researchers was perceived as positive and possible. As stated by the subjects interviewed, skilled Guatemalan scientists contribute to furthering research on relevant topics, advance technological developments, allow deeper labor market specialization, and have a robust understanding of evidence-based knowledge and its application to real-world problems. Moreover, it was identified that the GSD allows the representation of an additional aspect of Guatemala: that of highly skilled, hard-working professionals who are passionate about science, technology, and development and make valuable contributions in their field.

Scientific diasporas are fundamental for science and research capacity development. They are also recognized as a solid force to encourage novel and fruitful collaborations abroad; therefore, governments, civil societies, other organizations, corporations, and academic groups are needed. In the case of Guatemala, no public policies or legislative actions, nor existing collaborative structures focused on creating possibilities of engagement with GSD were identified. In terms of Foreign Policy, attention is mainly centered on irregular and vulnerable forced emigration, particularly toward the United States of America. As for public policies in science and research, the single initiative identified as a consistent activity to connect GSD with their country was *Converciencia*, which is not a program nor a policy, but an event or recurrent activity (over 15 years of implementation with changes over time).

Evidence suggests that the GSD cooperates with governmental institutions such as the National Secretary of Science in established programs such as *Converciencia* or the International Guatemalan Scientists Network. Nevertheless, they complain about the lack of policies, bureaucracy, or non-existence of engagement programs. This is the best scenario. The other governmental institutions hadn't created any program or platform in most cases. The GSD has not found support in the Ministry of Foreign Affairs or Embassies, among other government institutions.

Guatemalan universities and research centers have a fundamental role in developing new strategies to increase inclusiveness and actively engage the GSD by responding to contemporary science's global demands and needs as part of their programs. They need to expand local scientists' participation by informing them about existing programs and promoting and sharing authority in engaging them in all the research decision-making processes. The inclusion of GSD is an opportunity for creating models of governance of science centers based on the participation of local and abroad scientists' experiences as integral components alongside the ones who traditionally place the role of these centers as a provider of trained persons and basic knowledge.

The GSD suggested strategies using artificial intelligence and machine learning to data-mine all the Guatemalan scientists' online professional information and publications. Members of the GSD also suggested creating a platform to enable better communication between the diaspora and the different key actors within the Guatemalan science, research, and innovation system. They indicated it is relevant to include actors and decision-makers from the government, higher education, research institutions, and the industry, relevant stakeholders representing international partners, non-governmental organizations, and civil organized social groups.

International partners play a relevant role in the engagement of the GSD, mainly through alumni associations, such as the Fulbright and Chevening alumni networks, having an active connection amongst alumni. International partners also provide research grants, scholarships for postgraduate studies, and short courses in their countries of origin. Other international (bilateral-multilateral initiatives) are also relevant to the GSD. They are sources of grants, awards, and spaces for researchers and scientists to connect and engage with their peers not only from their countries of origin but also from other regions with similar needs and challenges i.e., the International Network for Advancing Science and Policy -INASP-, the Organization of Women in Science for the Developing World-OWSD-, the World Academy of Science TWAS, the InterAcademy Partnership IAP, to cite some.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: https://owsd.net/network/guatemala, https://redcti.senacyt.gob.gt/portal/index.php/investigadores/directoriocti.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee from the University of Technology of El Salvador (UTEC). The patients/participants provided their written informed consent to participate in this study. All participants were asked to sign an electronic informed consent form prior to their participation.

AUTHOR CONTRIBUTIONS

KB: conceptualization (lead), data curation (lead), project administration (lead), methodology (lead), resources (lead), validation (lead), and writing—original draft (equal). CR-O and SA: conceptualization (equal), data curation (equal), supervision (lead), project administration (equal), writing original draft (equal), and visualization (equal). NYOO, MA, AD, and GO-C: investigation (supporting), visualization (supporting), writing original draft (equal), and writing—review and editing (equal).

SM: formal analysis (equal), investigation (supporting), data curation (equal), and resources (equal). GM-B: critically analyzed the manuscript and suggested edits. NYOO: investigation (equal), data curation (equal), writing original draft (equal), and visualization (supporting). All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

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OPINION
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The Potential Contribution of the Scientific Diaspora to Enhance Marine Science in Guatemala

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INTRODUCTION

The republic of Guatemala has 402 km of coastline, including the Caribbean Sea and the Eastern Pacific Ocean (CONAP, 2009). Despite having a privileged geographic location and rich marine-coastal biodiversity, it has been considered that *"Guatemala has lived with its back to the sea"* (Carrera et al., 2012; González-Bernat and Clifton, 2017). This fact is observed through a substantial lack of data and information, which denotes that those marine resources in Guatemala are understudied and subsequently poorly managed. Partially because of poor inter-institutional coordination, scant budget allocation, and lack of human resources (Carrera et al., 2012; González-Bernat and Clifton, 2017, 2021a,b; Caviedes et al., 2021). One of the most relevant reasons that lead to poorly marine resources management is the lag in science and technology in the country.

Limited offer of university programs is insufficient both in terms of coverage (number of programs available) and quality (part-time dedication with little scientific production) (Bonilla, 2021; RICYT, 2021; Martínez, 2022). Consequently, for decades some Guatemalans tend to apply for international cooperation scholarships, university discounts, student loans, or their own sponsorship to educate themselves (Bonilla and Kwak, 2015; Bonilla, 2021). Once graduated, these professionals often decide to establish their residence and workplace in other countries, among other factors, due to the lack of job opportunities and professional development in the universities of their home country (Charum and Meyer, 1998; Mera, 2011; Bonilla, 2021). Therefore, these Guatemalan scientists residing abroad make up the Guatemalan scientific diaspora.

The scientific diaspora could become a resource of interest for the country since it is a group of qualified people who know well the culture of the country where they reside. It might be the perfect opportunity to connect with academic and scientific actors from the productive sectors and government entities (Echeverría-King and Prieto, 2021). Also, they could be a bridge for the execution of cooperation projects and activities, facilitating the exchange and transfer of knowledge and technology (Palacios-Callender and Roberts, 2018; Echeverría-King and Prieto, 2021; Lopez-Verges et al., 2021). In this context, this article aims to describe the potential of the scientific diaspora and how it would contribute to strengthening this area of knowledge.

SCIENCE IN GUATEMALA

The latest report on the State of Science (2021) places Guatemala as one of the countries with low scientific development and a possible cause is the scant budget allocation and lack of human resources. Guatemala barely invests 0.03% of the gross domestic product of science and technology. The concern is that this allocation has not changed in the last decade due to the government and private companies' lack of interest and commitment to granting the necessary economic resource to the development of science and research (Martínez, 2022). In 2019, the spending on investment and development in the country was US$39.81 million (including the investment in the academic sector and the state; RICYT, 2021). Therefore, Guatemala continues to be a country that does not invest in science since it does not consider this a priority. This fact occurs because it is not understood that the material wealth of countries goes hand in hand with their technological development and the fact that investment in science is a long-term strategy that supports the management of biological resources (Pazos, 2020).

Furthermore, the number of researchers in the country is the lowest in the Central American region and Latin America. Guatemala reported 508 researchers (2019), while Costa Rica and El Salvador reported 3,781 (2018), and 1,030 (2019) researchers, respectively. Meanwhile, the benchmark of South America is Argentina and Brazil, with 90,747 (2019) and 421,838 (2018) researchers, respectively. Therefore, this places Guatemala as the country with the lowest number of researchers and limited scientific production. In 2019 Guatemala registered in SCOPUS 2.2 publications per 100.000 inhabitants, while in the same year, Costa Rica, Argentina, and Brazil registered 27.2, 33.2, and 41.6 publications, respectively (RICYT, 2021).

The positive trend for national scientific production in Guatemala in the last decade has been increasing, with 147 publications in 2010, 232 in 2013, 283 in 2016, and 357 in 2019 (Monge-Nájera and Ho, 2018; RICYT, 2021). This positive trend is also indicated in the latest report on the State of Science (2021), which report that between 2016 and 2019, Guatemala dedicated 53.3% of its scientific production to issues related to one of the Sustainable Development Goals (RICYT, 2021). This is encouraging, knowing that the scientific community has shown a greater interest in topics that aim to study these goals that define all the priorities that exist at the global level concerning the significant challenges that are faced to advance sustainable development (UNDP, 2022).

MARINE SCIENCE AND GUATEMALAN SCIENTIFIC DIASPORA

After agreeing with Carrera et al. (2012) and González-Bernat and Clifton (2017) that *"Guatemala has lived with its back to the sea,"* it is necessary to establish the reasons why the development of marine science in Guatemala has not been given the relevance it deserves. At least two factors could explain these causes:

- *Limited offer of university programs*: Most of these professionals have received their training in two main ways. (1) Pursue an undergraduate degree in Biology, or undergraduate degree in Hydrobiological Resources and Aquaculture that eventually allows specialization in marine sciences, (2) Pursue a postgraduate degree in Guatemala (master's degree in Marine and Coastal Sciences is the only option), or abroad (MSc or Ph.D. in Marine Science, Oceanography or related). Thus, many of these professionals do not have training in marine sciences *per se* but rather become trained in this area of knowledge at a later stage of their degree.
- *Low and Insufficient Funding*: In 2019, Latin America made an investment that represented 0.56% of the gross domestic product of science and technology. The Central America region invests between 0.03 and 0.39%, while the South America region invests between 0.14 and 1.6% (RICYT, 2021).

Although both factors result in a shortage of skilled scientists and technical workforce to cover the country's needs for research & development (Tarifeño-Silva, 2002), in the last decade, a positive trend in national scientific production prevails in Guatemala, which is an encouraging step for the country development. In marine sciences, it is not the exception. However, beyond the evident increase in scientific activity in marine science in Guatemala, the degree of development does not seem sufficient to address the main emerging issues of the discipline, which was recently outlined in the international agenda (National Research Council (NRC)., 2015; Intergovernmental Oceanographic Commission - United Nations Educational, 2017). Most of the scientific publications related to this area of knowledge in the last decade, agree that one of the main problems in Guatemala is the lack of data and updated information. Such as, the description of the fishing fleet and its landings, consumption of hydrobiological products and their production, and the distribution and abundance of marine species, among others (e.g., Brittain, 2016; González-Bernat and Clifton, 2017, 2021a,b; Hernández-Padilla et al., 2020; Muñoz et al., 2021).

The Guatemalan higher education system does not offer the conditions to train and educate marine science scientists and lacks permanent financing for adequate scientific development. This led to the notion that there are several highly-trained professionals in marine sciences in Guatemala's scientific diaspora. To try to identify and characterize this scientific diaspora, the directory of members of four organizations that bring together Guatemalan professionals who do science in the country or abroad was consulted. The total members of the organizations and the number of professionals working in marine sciences were recorded, also identifying whether they work abroad (**Table 1**).

Nineteen marine science professionals registered in one or more of these organizations have been identified. However, most of the members are registered under a university's affiliation without specifying a faculty or research center. They also do not indicate academic background, research, and specific profession. Therefore, it was impossible to identify several of these members if they worked in this area of knowledge. Also, through a systematic search of available literature related to marine sciences in Guatemala in the ISI Web of Science and SCOPUS databases,

TABLE 1 | Number of marine sciences professionals and researchers that are registered in a Science and Technology directory in Guatemala.

Organization	Total Members	Marine Science Members	Scientific Diaspora[(a)]
International Network of Science, Technology, and Innovation (RedCTI)[1]	194	1	1
Academy of Medical, Physical and Natural Sciences[2]	86	-	-
National Directory of Researchers of the National Secretariat of Science and Technology (DIN- SENACYT)[3]	16[†]	6*	1
Organization of Women in Science for the Developing World–Guatemala chapter (OWSD-GT)[4]	440	12*	6

Academy of Sciences–Directory of members is restricted in three general areas, Physical, Natural and Medical Sciences.
[†] DIN-SENACYT–In the directory it is not possible to search by specific profession. For this, the research catalog of the area of Earth, Ocean and Space Sciences was reviewed. (*) Includes only ocean science research.
**OWSD-GT–Members that indicate their relationship with marine sciences among their academic background, research, and profession were reviewed.*
aScientific Diaspora–The same professional registered in three organizations.
[1] RedCTI https://redcti.senacyt.gob.gt/portal/index.php.
[2] Academy of Medical, Physical and Natural Sciences https://www.acacienciasgt.org/index.php/2-uncategorised/8-people.
[3] National Directory of Researchers of the National Secretariat of Science and Technology https://fondo.senacyt.gob.gt/portal/index.php/catalogo.
[4] OWSD Guatemala https://owsd.net/network/guatemala.

it was found that some of these authors are not registered in any of these organizations, and some have affiliations with the prominent universities of the country. This agrees with Monge-Nájera and Ho, (2018) that the authors with the most significant scientific production in Guatemala coincide with the leading institutions and suggests that high-quality research depends, to a large extent, on individual researchers who lead production in institutions.

The initial search identified 19 marine science professionals, of which 6 are part of the scientific diaspora (although one is registered in three of the four organizations consulted; **Table 1**). Of these, only three contributed to the scientific development of marine science in Guatemala, with scientific publications in the last decade. Perhaps more professionals have contributed to scientific production or knowledge transfer and cooperation, but we do not know because much of the work done by diasporas is not published and is therefore under-reported. Also, these organizations that bring together Guatemalan scientists and professionals must periodically update their database, and this information must be more dynamic and accessible, so that the benefits are seen as more participatory.

LINKING THE SCIENTIFIC DIASPORA

Regardless of location, it has been described that the scientific diaspora can actively contribute to (1) *Strengthen the higher education system*, contributing to the design of national and regional postgraduate programs, and increasing the offer of these university programs, (2) *Increase productivity and scientific impact*, (3) *Generate mobility opportunities* (executing projects, cooperation activities, facilitate the exchange, and transfer of knowledge and technology), and (4) *Be a bridge between science and decision makers*, guiding government policies and regulations (Scientific Diplomacy) (ICMPD, International Centre for Migration Policy Development, 2019; Bonilla, 2021; Lopez-Verges et al., 2021). Also, a well-connected diaspora may aid reinsertion strategies (Stehli, 2020) and help design national and regional postgraduate programs that could increase intraregional mobility, strengthen regional collaboration, and increase productivity and visibility of research (Lopez-Verges et al., 2021).

The linkage mechanisms could start with the joint participation of the Ministry of Foreign Affairs with the National Secretariat of Science and Technology (and other relevant actors, e.g., the National Academy of Sciences, Universities) to identify this scientific diaspora and generate dialogue between several actors involved. Also, to map the scientific diaspora, a website can be created through several initiatives that allows the registration of these scientists abroad to understand how many, where they are, and the paths of these scientists around the world. At this same line, two successful cases can be mentioned of mapping the scientific diaspora, Portugal (GPS, 2022) and Costa Rica (Marques et al., 2020; HIPATIA, 2022; Pasamontes, 2022). The global health and economic crisis caused by the COVID19 pandemic promoted higher informal networking through social networks (Twitter, Facebook, Instagram). This served, and could continue, as a tool to identify, connect and create conversation spaces with some members of the diaspora.

DISCUSSION

Undoubtedly, one of the greatest challenges that is facing not only Guatemala, but also several countries in the region and the world, is the national investment in science, technology, and innovation. Guatemala barely invests 0.03% of the gross domestic product (equivalent to US$ 2.40 per inhabitant), which means that a large part of the advanced human capital leaves or remains outside the country, with the subsequent costs for the development of sciences in Guatemala. For this reason, it is necessary to improve dialogue and coordination between the sectors for the development of joint actions that allow opening spaces for communication with the scientific diaspora for the generation of alliances and cooperation that, from the scientific perspective, have an impact on social benefit.

Due to the lack of research in this field in Guatemala, it is hoped to have made a helpful initial contribution and have highlighted some of the core aspects of the contribution of the scientific diaspora. Given the urgency of the current challenges facing the oceans, all available methods to support effective and equitable responses to your study should be used to the best of their ability. It is believed that the link with the diaspora can be important in this matter, by strengthening the system of science and higher education both in Guatemala and in the region.

Finally, it is suggested as a good start, to map the marine scientific diaspora through a systematic and quantitative review of the publications of Guatemalan authors and to characterize their international collaborative networks.

AUTHOR CONTRIBUTIONS

Both authors have made a substantial, direct, and intellectual contribution to the work and approved it for publication.

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Engaging Honduran Science Diasporas for Development: Evidence From Three Consolidated Networks

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Honduras' underdevelopment of the higher education system, national economic constraints, and low investment in science and technology (S&T) have created significant challenges in training, employing, and retaining its science workforce, resulting in what is known as "brain drain" in literature. There are no official statistics of Honduran scientists who have established their residency abroad, nor the Honduran scientific diasporas (HSD); however, various diaspora networks provide evidence of their existence and engagement in their home country. This study takes an empirical approach and explores experiences of networking and engagement of the HSD for the development of Honduras. Methodologically, a qualitative approach and a phenomenological design were used. The data were collected through documentary review and semi-structured interviews with 21 key respondents from three identified HSD networks: Honduras Global (HG), the Organization of Women in Science for the Developing World, Honduras National Chapter (OWSD Honduras), and the Alumni Association of the Zamorano Pan-American Agricultural School (AGEAP-Zamorano). The holistic analysis of HSD's engagement provides evidence of existing registry gaps. Neither the S&T agents nor the Honduras Foreign Policy have identified, mapped, and characterized Honduran scientists' emigration patterns. Evidence suggests the willingness of the HSD to transfer knowledge, build bridges, and facilitate access to world-class research practices to their peers residing in Honduras and interact with broader sectors of the Honduran society.

Keywords: science diaspora, Honduras, S&T policy, S&T capacity building, Central America, Honduras Global, OWSD, Escuela Zamorano

INTRODUCTION

For decades, the international mobility of scientists from the Global South to the North has been the subject of several fields (Barré et al., 2013; Geuna, 2015). Such mobility has been less examined when considering the establishment of permanent residence of such scientific workforce in advanced countries (long-term immigration) as opposed to quick schemes of mobility (i.e., participation in training and short-term educational programs). As the global competition to attract highly educated individuals has intensified, the emergence of phenomena, known as "brain drain" (Durmaz, 2020), "human capital flight" (Popogbe and Oluyemi, 2020), and "academic exodus" (Heffernan and Heffernan, 2020), has dominated the literature. These concepts assume the loss of talented and outstanding professionals who flee from one country or region (developing) instead of another (developed). However, new approaches propose a paradigm shift toward "brain circulation" (Fangmeng, 2016), "knowledge diaspora networks" (Meyer, 2011), and "expatriate scientists" (Barré et al., 2013), addressing the formation of science diasporas (SD) from a more optimistic perspective. The scientific and technology diasporas (S&T diasporas) have been defined as "self-organized communities of expatriate scientists and engineers working to develop their home country or region, mainly in science, technology, and education" (Barré et al., 2013, p. 83). In other words, the S&T diasporas are formed by highly skilled scientists, researchers, and engineers, who live, work, and reside in countries other than their nation of origin. Until recently, the most vocal concern pointed to the occurrence of brain drain; however, in the digital area, instead of insisting on the return of the highly skilled migrants, the emphasis is placed on the circular exchange and transnational mobility (Stopić, 2013). From a global perspective, it is essential to focus on the interlocking webs of international and national development organizations, international organizations, public institutions, and migrant associations and networks. These provide a roadmap for this wide-ranging terrain of structural transformation. In this context, it is helpful to think about migration and development in a transnational circulation, placing the migrant at the center of attention, and identifying them as a cooperation and development agent (Meyer, 2011). Notwithstanding, the emphasis is placed on the role of financial remittances. The activities of organizations and the positioning of agents within networks constitute a social transformation work; in this way, engaging with the diaspora for the benefit of development has thus become an essential strategy of many immigration states.

The role of diasporas in development strategies, poverty reduction, and economic growth is attracting considerable policy interest, involving diasporas, host countries, and home countries (Ionescu, 2006). Barré et al. (2013) mention that some basic S&T diasporas' activities are "building a scientific community, gathering, managing, and circulating information about members' skills, organizing scientific events and training, and contributing to S&T infrastructure in the home country" (p. 102). These diasporas are special agents for developing in Northern countries issues specific to the scientific agenda of the South. It is advantageous that these S&T diasporas have a clear understanding of the reality and problems faced in their countries of origin which in turn facilitate transnational interaction. Barré et al. (2013) studied various cases involving Latin American SD: one on the experience of non-profit organizations (NGO) in France (AFUDEST and ALAS), one on work in an international organization (UNESCO), and one about fieldwork with a government agency, Argentina's Secretariat for Science, Technology and Productive Innovation (SETCIP) (p. 406).

In Central America, the dominant paradigm is also "brain drain." In this region, the prevalent perception is that the lack of career opportunities and low S&T national capacities make it challenging to retain highly skilled and well-educated scientists and researchers (Bonilla, 2022). For this reason, accomplished scholars decide to establish their residence in other countries where the labor condition can meet their goals. Admittedly, the S&T ecosystems at the global, regional, and national levels in the digital age are experiencing incentives to turn brain drain into brain circulation, considering that these two concepts have been running long in the scholarly debate (Stopić, 2013). While accepting that scientific diasporas from countries in the Global South exist, a key question emerges: What experiences of engagement of such SD with their country of origin exist and which lessons can be extracted? This research attempted to delve into this question focused on the case of Honduras.

As a Central American country, Honduras is a scientifically lagging country, sharing the same obstacles as the region to keep their highly skilled professionals. Admittedly, according to Discua and Cerrato (2019), the country has started to recognize prominent Hondurans in arts, entrepreneurship, international business (Discua and Cerrato, 2019), and social enterprise of the Honduran diaspora (Discua and Fromm, 2018). As for science diasporas, there is no official or centralized database of the HSD built by any public institution (i.e., Ministry of Foreign Affairs, Secretariat of Planning, Honduras Institute of Science and Technology) in Honduras. Therefore, the authors applied an exploratory search for SD networks related to higher education, international cooperation, and skilled migration from Honduras. This is how three diaspora networks were identified: (i) Honduras Global, (ii) The Organization of Women in Science for the Developing World-OWSD Honduras National Chapter (OWSD Honduras), and (iii) Association of Alumni from the Pan-American School of Agriculture Zamorano School (AGEAP-Zamorano) (Details are presented in section Methods, **Table 1**). This study aimed to understand in depth the engagement experiences of the Honduran science diaspora (HSD) for the development of Honduras in the 2010–2022 period, specifically the HSD of the three mentioned networks. The produced knowledge in this research will help continue the conceptual and empirical development of the alternative optimistic perspective to migration outflows, emphasizing the circular exchange and transnational mobility in the migration–development nexus. Also, understanding the engagement experiences will offer feedback to improve and continue the work in this field because this is the first systematization in the country on this topic. The engagement is approached from an adaptation of the typology included in the theory of participation of the stakeholder and public engagement proposed by Reed et al. (2018). This is based on the agency (who initiates and leads engagement) and mode of engagement (from communication to co-production). They define participation:

> as a process where public or stakeholder individuals, groups, and organizations are involved in making decisions that affect them, whether passively via consultation or actively via two-way engagement, where publics are defined as groups of people who

TABLE 1 | Honduras diaspora engagement for development.

Type of engagement	Categories and operationalization	Operationalization/illustrative examples
Orientation	Top-Down: initiated and/or led by those with formal decision-making power who wish to empower interested parties with less power and diverse perspectives to make or contribute toward decisions	Approach in which an executive decision maker or other top person makes the decisions of how something should be done. This approach is disseminated under their authority to lower levels in the hierarchy, who are, to a greater or lesser extent, bound by them. Public policies, legislative actions/programs, guidelines.
	Bottom-Up: initiated and/or led by citizen, public or special interest groups with limited formal decision-making power	Approach in which is the piecing together of systems to give rise to more complex systems, thus making the original systems subsystems of the emergent system.
Direction	Unidirectional: Communication, Consultation	Experiences with passive audiences: e. g.., podcasts, webinars, scientific dissemination, presentations, online teaching
	Bidirectional: Collaboration between two parts	Experiences involving active exchange and co-creation between two clearly identified parties: e.g., Thesis review, project evaluation, research extension
	Multidirectional: Collaboration between multiple parts	Experiences with higher complexity with active exchange and co-creation involving clearly identified multiple parties. International projects collaborations with the participation of consortiums

Source: Adapted from Reed et al. (2018, p. 31).

> are not affected by or able to affect decisions but who engage with the issues to which decisions pertain through discussion and stakeholders are defined as those who are affected by or can affect a decision. (p. 2).

Considering the descriptive typology that attempts to explain the outcomes of engagement in any given context, **Table 1** shows the adaptation of the types of engagement of the SD as a guiding framework for this research.

SCOPE AND LIMITATIONS

A few limitations of the study must be acknowledged. Due to the lack of comprehensive databases of the HSD, results and findings are not statistically relevant. We instead focused on collecting and analyzing rich qualitative data to extract learnings from the experiences. In addition, the potential interviewees share a common characteristic: limited time available to participate in the study. At first, early and mid-career members of the HSD were more prone to experience. Therefore, we needed to run a complementary invitation to ensure further participation of established-career members. Finally, the temporal delimitation is relatively short (12 years); this obeys the characteristics of the HSD networks. Although AGEAP-Zamorano can be traced back a few decades of existence, it was just after the turn of the 2000s when the networking component took hold. HG was launched in 2011, while OWSD Honduras was launched in 2020.

METHODS

Methodologically, the object of study was approached through qualitative research and a phenomenological design (Creswell and Poth, 2018). Regarding temporality, information has been collected since the origin of two HSD networks: Honduras Global 2011–2022 OWSD Honduras 2021–2022. In the case of AGEAP-Zamorano, the availability of updated records delimited the period 2010–2022. Two sources of data were used: documentary review and semi-structured interviews. The documentary review covers files on the experiences in Honduras involving the HSD, including historical reports, institutional annual reports, strategic plans, annual operating plans, press publications with reports, audiovisual material, journalistic notes, and media coverage of the initiatives. In the second, the population of participants included members of the HSD belonging to the three mentioned networks; **Table 2** summarizes their characteristics.

The research technique chosen for this research was the semi-structured interview. This methodological tool is characterized by deciding in advance the type of information required, and based on the objectives, a script of questions is created; unlike structured interviews, these have the particularity of being more flexible concerning the order, priorities, or requirement of deepening (Bertomeu, 2016). This type of interview was chosen as it intends through the collection of a set of private knowledge, the construction of the social meaning of individual behavior, or the reference group of the interviewed subject, in this case, the HSD. Likewise, this type of interview facilitates the collection and analysis of social knowledge crystallized in discourses, which have been constructed by the direct and unmediated practice of the protagonists; therefore, it allows us to have a first approach to a topic that is largely unexplored in the country.

The inclusion criteria for the participants in the semi-structured interviews were designed to procure diversity in the representation of fields of knowledge, geographic location of residence among HSD, and balance in gender participation. The sampling was purposeful of the homogeneous and chain type (Creswell, 2015; Creswell and Poth, 2018). We established

TABLE 2 | Honduras scientific diaspora selected networks.

HSD Network	Characteristics
Honduras Global*	Honduras Global is a Foundation launched in 2011, inspired by the international network of "outstanding" Hondurans promoted by Sir Salvador Moncada, a prominent scientist with roots in Honduras based in the United Kingdom. As of February 2022, it has over 60 members, including artists, entrepreneurs, businesspeople, and scientists. All its members are Hondurans.
OWSD Honduras**	OWSD Honduras National Chapter is a community of Honduran women scientists formally established in July 2021. As of February 2022, it has 97 members, from which 29 report their place of residence and work abroad.
Zamorano Alumni***	The Association of Zamorano Alumni is a systematic networking platform established in 1965. As for 2022, there are nearly 9,000 graduates from over 30 countries of origin. The Alumni is organized in chapters based on their location, interests and affiliations, e.g., There are Alumni Zamorano Association in Europe, the United States, Asia, Africa and various countries in Latin America

*Database based on http://hondurasglobal.org/.
**Database based on http://owsd.net/network/honduras.
***Alumni Zamorano (AGEAP): Asociación de Graduados Escuela Agrícola Panamericana based on https://www.zamorano.edu/graduados.

contact with an official representative of the networks. We visited their websites to obtain a list of members with their general characteristics, then selected the possible participants according to the inclusion criteria, and thus, were invited by email. When the interviews were done, we asked for recommendations from other participants. The profiles of the participants are summarized in **Table 3**.

DISCUSSION AND FINDINGS

Integration of the Honduran Scientific Diasporas (HSD)

The understanding of the participants of the concept of "scientific diaspora" varies significantly. While most of them did not have an in-depth knowledge of the term, many associate it with migration and international mobility. Nearly all the participants related the term scientific diaspora to "brain drain." Traditionally, this connotation has a negative view of the consequences of subtracting highly qualified people from their place of origin in the workforce.

In this sense, AGEAP2 points out the following: "the only thought that comes to my mind when I hear "scientific diaspora" [...] (is) brain drain. [...] I feel my country loses this valuable talent due to the current situation in Honduras and the few opportunities for us to work there as scientists, especially the young people." OWSD-ND agrees and adds: "the term [HSD] suggests the presence of Hondurans deployed in other universities around the world; this one is also a sign of the brain drain which at the same time speaks highly of the scientific capacity that we have in Honduras." It is important to emphasize that participants referring to the situation of lack of opportunities tended to focus more on the reasons for the departure than on the possible damage that their country of origin could face due to the release of large numbers of skilled human capital. Another recurrent association of terms was diasporas in emigration. Yet, when participants consider themselves as migrants, some of them point out apparent differences from the vulnerable migration Honduras has experienced for decades. HG1 and HG2 agreed that emigrating with proper documentation (visa, valid passport) and institutional support marks a different path toward relocation compared with the precariousness of irregular (economic) emigration from Honduras to the United States of America. In this sense, other terms loaded with more positive perspectives are expatriates, skilled migrants, and international scholars. The value assigned to the term "scientific diaspora" remains relatively positive or neutral for most participants. Such is the case of OWSD-HN3, who states: "[as SD] When I think of seeds, I think of a group of people who come from the same place and are dispersed elsewhere," OWSD-HN6 concurs: "my background as biologist gives me notion [of diaspora] as seeds planted in various places doing science and research."

Another association to SD was the expressed desire to remain linked to their country of origin and contribute to improving the Honduran population's lives. HG4 noted the following "for one reason or another, we live outside our country, but we maintain a very closely linked with what is happening there and want to contribute to improve things." In repeated interventions, participants emphasized their desire to "contribute" or "give back to the country," especially when they have benefited with scholarships or funding based on their nationality. These attitudes are consolidated from the exposures the HSD have to better research practice in their country of destination, which gives them an awareness of the various science gap existing with Honduras, for example, infrastructure, human power, and institutional support. AGEAP6 and HG7 gave similar statements.

As for the motivations for organizing and belonging to their respective HSD networks, it was found that most participants report three levels of reasons: personal, professional, and organizational. Participants listed among their motivations as building win–win scenarios. They benefit in their career development while also offering their time, knowledge, skills, and contacts to carry on further reaching activities. Joining a community where they interact with peers and actors from other sectors is part of their objectives. Participant OWSD-HN1 indicated: "I felt this need to interact with colleagues, share interests, and build alliances."

On the contrary, among the people whose motivation relates to organizational aspects, it can be observed that most participants have altruistic motivations and find their networks enable them to pursue their goals. They sought to share the knowledge acquired abroad, either with vulnerable populations or with their peers. Such was the case of OWSD-HN3, who declared: "[my motivation to be part of my network is] to disseminate science results and engage in teaching so that it can encourage girls for them to study in STEM [science, technology, engineering, mathematics] careers." The goal that various

TABLE 3 | Key respondents semi-structured interviews HCD selected platforms.

HCD network	Code	Experience	Trajectory	Destination	Gender equity	Field of expertise
Honduras Global (HG)	HG1	Researcher and Scholar	Established Career	Bern/ Switzerland	F	Agricultural Sciences/Sustainable Development
	HG2	Researcher and Bioinformatician	Early Career	Canada/ British Columbia/	M	Health Sciences/Cancer Epigenomics
	HG3	Postdoctoral Researcher	Mid-Career	Denmark/ Odense	M	Food Sciences/Microscopic Composition
	HG4	Researcher, Senior Lecturer	Established Career	United Kingdom/ Lancaster	M	Business Research/Family Businesses
	HG5	Graduate Student Doctoral Program	Early Career	The Netherlands/ Amsterdam	F	Health Sciences/Epidemiology
	HG6	Graduate Student Doctoral Program	Early Career	France/ Paris	M	Health Sciences/Virology
	HG7	Senior Researcher	Established Career	Belgium/ Vrijes	M	Psychology/Neurosciences—Emotions
OWSD Honduras (OWSD-NH)	OWSD-HN1	Graduate Student Doctoral Program	Early Career	Spain/ Valencia	F	Environmental Sciences/Geographic Information Systems
	OWSD-HN2	Graduate Student Doctoral Program	Early Career	United States/ Washington	F	Mathematics/Computational Mathematics
	OWSD-HN3	Postdoctoral Researcher	Mid-Career	Mexico/ Merida	F	Organisms and Biological Systems/Plant Molecular Biology
	OWSD—HN4	Researcher Industry	Mid-Career	Spain/ Valencia	F	Chemical Engineering/Nanotechnology
	OWSD—HN5	Graduate Student Doctoral Program	Early Career	Mexico/ Mexico City	F	Economic and Financial Sciences /Social Innovation and Social Responsibility
	OWSD—HN6	Senior Scholar	Established Career	Germany/ Kaiserslautern	F	Organisms and Biological Systems/Environmental Change
	OWSD—HN7	Senior Researcher	Established Career	United States/ California	F	Health Sciences/epilepsy Neurosciences
Zamorano Alumni Association (AGEAP)	AGEAP1	Graduate Student Master's Program	Early Career	The Netherlands/ Gelderland	M	Food Sciences and Technology/Food Chemistry
	AGEAP2	Graduate Student Master's Program	Early Career	USA/ Miami	F	Livestock Sciences/Genetics
	AGEAP3	Graduate Student Doctoral Program	Early Career	USA/ Louisiana	M	Nutrition and Food Sciences/Food Innovation
	AGEAP4	Graduate Student Doctoral Program	Early Career	USA/ Alabama	F	Poultry Sciences/Infrastructure
	AGEAP5	Associate Professor	Established Career	USA/ Texas	M	Food and Resource Economics/Sustainable production
	AGEAP6	Project Officer	Established Career	Switzerland/ Lausanne	M	Environmental Engineering/Risk Management
	AGEAP7	Senior Researcher and Consultant	Established Career	Colombia/ Bogota	M	Agricultural Sciences/Soil yield and bioproducts

N = 21; F, = Female (N = 11); M, = Male (N = 10).

members of the HSD recurrently pointed out was exercising influence to improve the living conditions in Honduras.

The HSD shows a concentration in two geographic destinations, the United States and Europe. For a long time, the United States has been perceived as a land of economic opportunity by Hondurans (OAS-IDB, 2021), who for decades have singled out this country in North America as a priority destination, mainly for economic migration. This has created bonds and migration flows from Honduras, also found in skilled migration. This is partly explained by geographic proximity and the notoriety of American universities in Honduras. Another factor, explaining the concentration of the HSD in the United States, Canada, and Europe, is the provision of scholarships for training at master's and doctoral levels, for which Honduran citizens have been eligible for decades. In this sense, other countries of destinations that also support Honduran graduate students (notably Taiwan and South Korea) have engaged in cooperation with Honduras in the last decade. Therefore, the presence of HSD in Asian countries seems to be more limited. Complementarily, participants from the three HSD networks highlighted the overwhelming concentration of its members in North America and Europe.

Engaging the HSD (Types of Engagement)

In analyzing the types of engagement involving the HSD, two categories guide the presentation of the main findings. The first elaborates on the types of engagement in the dichotomy Top-down/Bottom-up approach, and the second addresses the types of engagement according to the direction of the interactions: unidirectional, bi-directorial, and multidirectional.

Orientation of the Engagement: Top–Down/Bottom–Up Approach

The orientation of the engagement refers, on the one hand, to the Top-down approach in two main lines: the Engagement of the HSD promoted by (i) S&T policy agents and (ii) Foreign policy. These two cases involve the actions emanating from an authority. On the other hand, the Bottom-up approach refers to initiatives promoted by individuals, which evolve into networks, going from part to a system.

The HSD and the S&T Policy Agents

In Honduras, at the governmental level, the official development of science has been recent (limited progress in the last 30 years) and has not had consistency between the changes in government administration. Science has been given little priority and little funding, and no national plan has been published to date. Honduras has structured the National System of Science, Technology, and Innovation (SNCTI). Few government entities make up this system, lacking the integration with other actors, including universities, companies, non-governmental organizations, and civil society organizations. In this sense, no legal and officially expressed articulation forms a comprehensive and multisectoral system. In the light of this, the scientists in the majority reported that they have not heard about government initiatives that articulate the scientific diaspora in Honduras. They mentioned some initiatives that promote scholarships, such as *Becas 2020*, which encourages Honduran students to continue their studies abroad under the condition of returning to the country. The recognized Alumni Zamorano network, except for *Becas 2020*, informed us about HONDUFUTURO, a private institution that finances 50% of the scholarship (AGEAP 1).

The government barely promotes scientific initiatives, and it makes sense with the lack of information the researcher reported. The main question is, how could they return to a country that does not provide the minimum conditions to create opportunities to research and overcome the brain drain. In the digital era, where virtuality is an essential element of development, the "brain circulation" of scientists of the Global South could increase the sustainable development of their countries, taking advantage of the resources and networks of their residency countries. OWSD-HN5 states that the "government should take advantage of my new knowledge produced by Hondurans. Still, we generated this disconnection with researchers residing in other countries that could be used for the development of Honduras." Several participants mentioned that consecutive governments of Honduras had few public institutions interacting with researchers and scientists in general, let alone those nationals from Honduras living abroad. AGEAP2 uses the example of the Direction for Innovation and Technology (DICTA), which has not fulfilled its role as a public research institution; no scientists work on researchers' projects there. DICTA employs officers with inadequate backgrounds; there is no STI (science, technology, and innovation) functional ecosystem that provides conditions to Honduran researchers. AGEAP 3 mentioned that "every Honduran would like to contribute directly to the development and return to their home living in Honduras. However, it seems that the governments are not interested in engaging us." AGEAP7 provided a practical action taken by a Honduran public institution. They who acknowledge the critical involvement of the *Secretaria Técnica de Planificación y Cooperación Técnica* (SEPLAN[1]). in the partnership which resulted in the creation of *Honduras Global* (HG) in 2011. This initiative—HG—is referred to by most of the participants in this study as the most known platform to engage the HSD in the development of Honduras.

HSD and the Honduras Foreign Policy

Honduras's foreign policy concerning S&T has been practically reduced to administering international cooperation to educate and train promising young researchers. In other words, they were handling fellowships and scholarships to train graduate students in master's and doctoral programs in international universities. Yet, various governmental institutions, including the Ministry of Foreign Affairs, lacked systematic and transparent practices (Bonilla and Serafim, 2021). The connection between the scientific diaspora within mechanisms to contribute to tackling the issues of their country of origin, in the case of Honduras, has not been explored. According to Balakhrisnan (2018), Diplomacy for Science is understood as promoting international science cooperation, a dimension of Science Diplomacy that could create evidence-based public policies if this goes in

[1] https://www.giz.de/en/worldwide/138.13.html

line with government priorities. However, most interviewed members of the HSD indicated interactions with the embassies, consulates, and diplomatic missions of Honduras accredited in their countries/cities of destination regarded only to migration-related procedures (e.g., renewal of passport, emission of the national identity card), with not a single mention of purposeful engagement in their capacities as scientists. They reported no interest in the embassies trying to connect them to the country. HG3 explained "concerns about [inexistent] channels to connect the HSD with scientific projects in Honduras because of the lack of interest from the Embassies abroad."

The foreign policy of Honduras has focused mainly on reducing the forced-irregular emigration to the United States of America. According to Meyer (2022), over the 2010–2020 decade, a pervasive combination of factors has triggered the dramatic phenomena of the Caravan of Migrants, in which Honduras (along with Guatemala and El Salvador) has expelled their citizens. Such factors include violence and repeated droughts linked to climate change that has increased food insecurity, particularly for subsistence farmers in the Dry Corridor of Central America.

In Central America, governments, academia, and the private sector increasingly recognize the importance of science, technology, and innovation (STI) as drivers of long-term, sustainable growth (Padilla Pérez, 2013). In the same way, the government of Honduras recognizes the importance of promoting, guiding, and encouraging scientific, technological, and innovation advancement to formulate medium and long-term plans. However, there is a lack of communication with scientific communities and the policymakers, despite the country leading on a legal basis and proper institutional framework supported for the parameters given by the international cooperation system. Science Diplomacy plays an important role that bridges both arenas of science and diplomacy to face global challenges. Due to emphasis on the term, science diplomacy is the use of scientific collaborations among nations to address the common problems confronting twenty-first-century humanity and build constructive international partnerships (Fedoroff, 2009). One of the approaches of science diplomacy addresses the importance of scientific networks informing public policies. Scientific communities play a vital role in advancing and updating knowledge in the region, promoting strategies for governments, universities, research centers, and civil society. Mainly, these strategies seek to work on Central America's integration of knowledge to encourage exchange, capacity building, and high-level training in the region. At this point, Honduras lacks this expertise; however, the challenge ahead is to build on the promising first steps and to enhance the contribution of research to sustainable development.

Bottom–Up Engagement to the HSD (Honduras Global, OWSD Honduras, Alumni Zamorano)

In the absence of government support, networks and organizations based on individual connections, such as Honduras Global, OWSD Honduras, and Alumni AGEAP-Zamorano, have played a significant role in articulating and engaging the HSD with their country of origin. The referred networks have taken steps forwards in achieving their objectives. Various participants offered examples of other networks organized around scholarship programs such as Fulbright (the United States of America), DAAD (Germany), Chevening (United Kingdom), and MASHAV (Israel), among others. However, they also pointed out that the level of engagement involved mainly dissemination of the scholarships and promotion of the partner countries with limited attention to the root development challenges of Honduras.

Honduras Global

Honduras Global[2] is a foundation created in 2011 and promoted by Sir Salvador Moncada. Its foundational objective focused on identifying and connecting highly skilled and prominent Hondurans located in different countries and regions worldwide to facilitate the transfer of knowledge and talents and promote innovation and scientific, technological, and business development in Honduras. At the launching of the initiative, cooperation from the public sector (Secretary of Planning) and international partners (GiZ from Germany) provided support. Among its principal activities, its members organize and implement science dissemination events (podcasts, presentations, interviews) and collective events such as the Week of Science, which had various editions, until the COVID19 pandemic in which it was suspended since 2020. As of February 2022, it registered 49 associates with networks geographically active in North America and Europe.

OWSD Honduras

The OWSD Honduras[3] is the national section of the global Organization of Women in Science for the Developing World. It was established in October 2020 and is based in Tegucigalpa. OWSD as a worldwide organization has existed since 1989 as a unit of UNESCO; however, in the case of Latin America, it was not until 2019 that the first national section was created. OWSD Honduras was the fifth in the Latin American and the Caribbean region. Among the principal activities are creating a repository for identifying Honduran women scientists and their respective areas of study, disseminating scientific awareness through webinars, workshops, and seminars for the scientific community and the public, and organizing leadership training for women in STEM. A component of this network is incorporating Honduran women scientists residing overseas. As of February 2022, OWSD Honduras had 97 members, of which nearly 30% (30) reported their place of residence abroad.

Alumni Zamorano-AGEAP

The Pan-American School of Agriculture Zamorano was created in 1942 in Honduras as a technical-oriented educational project in agriculture and agribusiness. Since then, it has graduated over 9,000 alumni from 30 countries. The school has achieved regional recognition for its emphasis on leadership and commitment to developing its students' countries of origin. In 1965, the Zamorano Alumni Association[4] (AGEAP

[2]http://hondurasglobal.org/
[3]https://owsd.net/network/honduras
[4]https://www.zamorano.edu/capitulos-nacionales

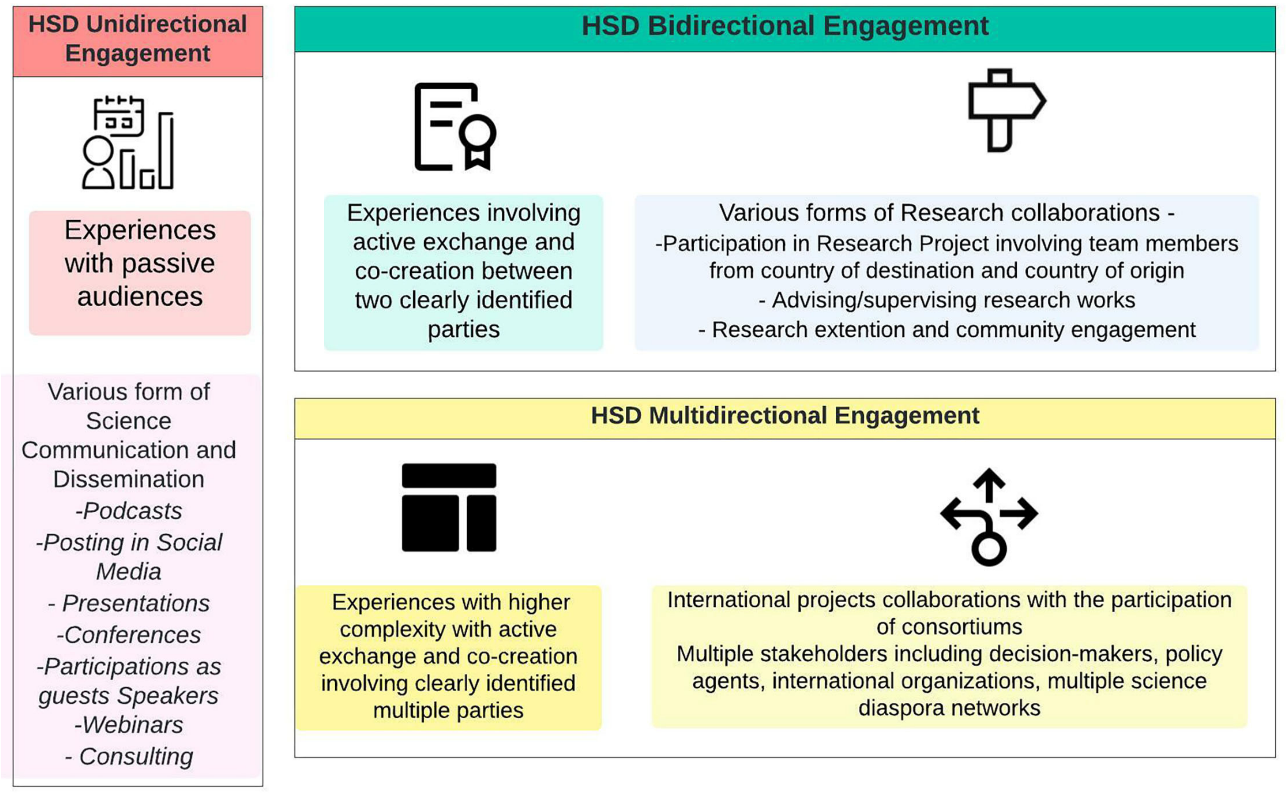

FIGURE 1 | HSD directional engagement.

is an acronym in Spanish for Asociación de Graduados de la Escuela Agrícola Panamericana). This network is structured in regional and national chapters in which its members actively engage in interactions among themselves and organize and participate in activities related to Honduras. Notably, active chapters in which Hondurans participate include Asia–Africa, Europe, the United States of America (a significant share of members have their residence in the USA), and other countries in Latin America. The main activities in which AGEAP-Zamorano participates emphasize self-development and career progression; however, they also participate in communication and dissemination activities targeting broader sectors of the Honduran society back in their country of origin.

Direction of the Engagement: Unidirectional–Bidirectional–Multidirectional

The types of engagement based on the direction of the interactions have been categorized in this research in three pathways: (i) Unidirectional (when the engagement activities involve an active agent, in this case, the member of the HSD and a passive audience), (ii) bi-directional (the engagement includes co-creation in the collaborative activities from at least two parties, in general, linking the HSD with peer scientists, students, and other actors connecting country of destination and country of origin), and (iii) multidirectional (the engagement enable complex interactions among parties in multiple locations).

Most activities in which the participants have engaged classify in the first category: unidirectional. Members of the HSD are in their early and mid-careers, and they commonly participate in science communication and dissemination activities, for example, webinars, fora, mentoring, and podcasts (OWSD-HN1, OWSD-HN4, and OWSD-HN5), teaching and training young students (OWSD-HN5 and OWSD-HN3). Once the HSD moves toward further career development, participation in bi-directional engagement arises. HG1 and AGEAP5 mentioned their contributions in academic exchanges and joint publications with peers working in Honduras. Likewise, HG2 and AGEAP4 said they collaborate in research among the members. Some scientists go beyond and explore how to contribute to the country's main challenges. For example, HG1 and OWSD-HN3 have developed initiatives involving multiple parties from various countries.

While HG1 promoted visits from Honduran students to various research facilities in European countries, OWSD-NN3 reported participating in a research project collaborating with the members of Alumni Zamorano, her *Alma Mater* in Honduras. AGEAP6 shares a clarifying example: "as I gained more seniority in my career, I was able to mobilize various millions of dollars in projects to be implemented by my affiliated institution in Europe in partnership with Honduran organizations back in my home country in fields related to climate change and environmental vulnerability." In the same way, other participants provided examples of developing projects on water and sanitation issues for vulnerable Honduran communities. An essential element has been found that strongly engages the HSD aims to close the inequality prevalent in Honduras. OWSD-HN2 stated, "I feel like an agent of change and on behalf of black women in Honduras who do not have many spaces won in education, mathematics, science, engineering, and many more." She advocates for minorities. These multidisciplinary female scientists know the social and economic challenges of the country very well, even more than the government is aware of, and they seek activities that are based on tackling these issues to contribute to sustainable development. AGEAP3 has been inquiring about participating in volunteer programs to create scientific capacity in government institutions without reaching good results. OWSD-NH7 shares: "My experience was coordinating a collaborative project of national coverage; this enabled scientific publications involving Honduran researchers and those from other countries. I was also involved managing funds so that this investigation was carried out in Honduras; I was responsible for applying for grants."

Figure 1 below illustrates the most recurrent examples of the engagement experienced by the participants.

CONCLUSIONS

Concerning the notions about the scientific diaspora, the study participants showed little knowledge of the subject and, therefore, a lack of identification with the term. The most frequent association in the responses was with the brain drain. Likewise, there was a consensus on the need to leave the country due to the lack of scientific opportunities and networks. Most of the people interviewed indicated that their motivation for joining was for organizational purposes, to guarantee them common spaces with people from their areas of work, and to collaborate in the development and improvement of living conditions in Honduras. It is essential to highlight those members of the HSD who participated in this study expressed their commitment to the development of Honduras and the knowledge, expertise, and benefits of the networks acquired during their stay abroad. However, one of the barriers they found is the lack of interest, opportunities, and resources, including the government and the Honduran ST&I ecosystem. Due to the country's lack of interest in engaging them, three initiatives studied in this research have played a pivotal role in harnessing the scientific diaspora to create a model for collaboration that promotes the scientific development of the country and meets the global goals.

Findings provide evidence that in the case of HSD, the bottom-up approach has been explored and yields results. Individual initiatives have fostered the creation and consolidation of networks that have drawn attention and support from external actors in their evolution. An example of this has been Honduras Global. In the case of OWSD, Honduras's actions toward Honduran women scientists can be traced back to the construction of networks and communities by appealing to the imitation example going from part to a system. Yet, in this second case, the support of a global organization (OWSD Secretariat located in Trieste, Italy) has proven central to the sustainability of this network. Finally, the case of AGEAP-Zamorano incorporates the strong support of the institution. In terms of engagement for developing their country of origin, Honduras Global and OWSD Honduras show the most substantial emphasis on exerting the positive influence of their members to contribute to improving national S&T capacities and living conditions in Honduras. The case of AGEAP-Zamorano presents a solid focus on the career development of its members, having the effect of Honduras as a complementary goal.

We believe that this is the first step to delving into the topic of engaging the HSD. The contribution of this research is empirical. We present the first comprehensive analysis of experiences engaging the Honduras Scientific Diaspora for development. The study collects primary data from a new context such as Honduras and elaborates on the paradigm shift from the brain-drain approach, dominant in literature, to the new approach of Science Diplomacy and attention provided by the foreign policy to map the migration outflow of Honduran scientists. The emphasis is placed on the circular exchange and transnational mobility in the migration–development nexus.

DATA AVAILABILITY STATEMENT

Publicly available datasets were analyzed in this study. This data can be found here: http://hondurasglobal.org/, https://owsd.net/network/honduras, https://www.zamorano.edu/capitulos-nacionales/.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by the Ethics Committee from the University of Technology of El Salvador (UTEC). All participants were asked to sign an electronic informed consent form prior to their participation.

AUTHOR CONTRIBUTIONS

KB took a leading role in conceptualization, data curation, project administration, methodology, resources, validation, and writing—original draft (lead). KA contributed to conceptualization, data curation, supervision, project administration, writing original draft, and supported visualization. RA-T involved in conceptualization (lead), data curation (equal), methodology (lead), writing original draft (equal), and visualization (support). SN involved in investigation (equal), visualization (supporting), writing original draft (equal), and writing—review and editing (equal). All authors contributed to the article and approved the submitted version.

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Emerging Technologies, STI Diaspora and Science Diplomacy in India: Towards a New Approach

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Utilizing the expertise and knowledge resources of the diaspora, particularly the scientific diaspora, has been part of the strategies of many countries. In the recent years, realizing the importance of the potential of the diaspora to contribute to national development and Science, Technology, and Innovation ecosystem, countries have used Science Diplomacy also to engage with the scientific diaspora. Science Diplomacy is hailed as an enabler and facilitator and is often seen in the context of international S&T collaboration or big science projects. But the use of Science Diplomacy for diaspora engagement calls for specific strategies and meaningful initiatives. India is one of the major developing countries that has given a major thrust to engaging with the scientific diaspora. India is also a leading player in the global Science Diplomacy arena. This article critically examines India's initiatives and strategies for engagement with the scientific diaspora. It points out that the Science Diplomacy dimension is missing in this. Using examples from other countries, recent thinking, and developments in Science Diplomacy, this study outlines an approach with some examples of strategies and initiatives for harnessing Science Diplomacy to enhance engagement with the scientific diaspora and create a win-win milieu for India and the diaspora. The approach takes into account the proposed and ongoing initiatives in emerging technologies in India, including quantum technologies and Artificial Intelligence. Such a framework will create a synergy among various programs and initiatives by using Science Diplomacy as a facilitator and catalyst. Under this framework, Diaspora is involved not only as experts and contributors to scientific advancements but also as stakeholders. This dual role of the STI Diaspora can bring a paradigm shift in traditional understanding and use of science diplomacy, particularly to engage and harness the potential of the STI Diaspora for Sustainable Development.

Keywords: Science Diplomacy, emerging technologies, SDGs, diaspora, brain gain

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INTRODUCTION

At a juncture where non-state actors are gaining prominence in building bonds between nation-states, science diplomacy becomes an avenue worth exploring in policymaking. Science benefits the entire humanity and transcends boundaries of language, ethnicity, and race, particularly in its ability to make human life easier. From the perspective of developing countries, this makes even more sense as the access to technology and knowledge from more advanced countries can be a great help. However, various barriers in the form of economic and narrow short-sighted political interests come in the way (Gottstein, 2003). This is where engagement with the diaspora of scientists, engineers, and doctors becomes effective.

Highly educated professionals command respect irrespective of how their country of origin is perceived in the host nation. Gottstein (2003) cites the instance of American culture being negatively perceived in Islamic countries and yet the scientific and technological achievements of that country being highly respected and envied. This shows the potential of science to build bridges where differences in culture and politics may be divisive. For countries from the Global South, diaspora presents untapped potential in this regard.

The discussions on "Brain-Drain" and "Brain-Gain" to "Brain-Circulation" and beyond signify the importance of diaspora. Discussion on brain-drain started in the 1960s and at that time the connotation was by and large negative. For example, according to UNESCO (Siegfried and Singh, 1987), "the brain-drain could be defined as an abnormal form of scientific exchange between countries, characterized by a one-way flow in favor of the most highly developed countries" (Siegfried and Singh, 1987). In this article, we adopt the definition of diaspora "as a category of practice, project, claim, and stance, rather than as a bounded group" (Brubaker, 2006). This definition, while going beyond the traditional usage of the term, facilitates conceptualizing diaspora in a broader sense, including practices, networks, mobilizations, and projects/programs.

Because of various factors, the migration of students, scientists, academics, and entrepreneurs has been continuing, and even when countries are offering more opportunities to the scientists and technocrats, they are also aware that migration need not be looked at as a purely negative phenomenon.

The report of the Global Commission on International Migration stated that Country of Origins (COs) should "establish an inventory of the skills base within the diaspora; develop programs that facilitate the transfer of skills and knowledge from the diaspora to their COs" (Global Commission on International Migration, 2005). For countries like Brazil, the Philippines, China as well as European countries like Greece and Ireland, harnessing the skills and talents of the diaspora, leveraging their networks, and connections for national development has been a priority, which is very well-manifested by them adopting different strategies. For example, Brazil adopted Rede Diáspora Brasil, as a plan to engage with the Brazilian diaspora of STI (Maastricht Centre for Citizenship Migration Development, 2021). Interestingly, it has also been suggested that ASEAN countries can complement their efforts by establishing a collaborative platform to pool the expertise as well as the transnational national networks of their Highly Skilled Diasporas (HSD) (Fok et al., 2021).

But among the diaspora, the STEM and/or STI diaspora, which consist of scientists, and technocrats, has a unique place on account of the importance of STI for national development and the central role of STI in economic progress. Hence, many countries including India are making efforts to incentivize these communities for contributing to capacity building in STI.

On the other hand, brain circulation and migration of talented persons including experts is likely to continue on account of the following factors which will result in the growth and expansion of the professional diaspora: (1) Globalization of the economy, STI, knowledge, and greater integration of countries with global systems; (2) Countries (e.g., Singapore) wooing talented persons from other countries to meet their needs and to expand their STI infrastructure, by offering incentives, granting citizenship on easier terms, and promoting expertise and entrepreneurship in selected sectors; (3) Young professionals and students with aspirations to move abroad for education and career; (4) the strengthening of ties of diasporas with their homelands, incentivizing migration as an option and as a normal phenomenon; and, (5) increase in international engagement of firms from the Global South, necessitating migration of talented personnel.

Moreover, the next generations among diasporas are likely to have ties with the homelands of the previous generations, irrespective of how strong, or weak the ties are. So, a pragmatic approach will be required to think in terms of "brain gain", "brain circulation" and making the best use of professional diaspora knowledge, expertise, and connections than to bemoan migration or reluctance of students to return after completing education/training.

In this context, more than one strategy and a multi-pronged approach are needed, including leveraging soft power. But as nations pursue talented human resources in STEM and make that part of their innovation strategy, it is not easy for developing countries to make the most of brain circulation. For example, the United Kingdom's innovation strategy states "Priority 1.1: Make the United Kingdom the most attractive destination for talented people and teams from the United Kingdom and around the world" (United Kingdom Research and Innovation, 2022). While, this dovetails with the United Kingdom's ambitions in Science, Technology, and Innovation, such strategies may also induce the migration of talented human resources afresh.

In the case of India, while there has been "brain-drain", diffusion of knowledge through migration of scientific labor is also important and there are opportunities and constraints in making use of diffusion of their knowledge (Kale et al., 2008). India has two categories of diaspora, i.e., Non-Resident Indians and Overseas Citizens of India (OCI). Overseas Citizenship of India (OCI) was introduced as a strategy for strengthening the ties of this diaspora with India so that dual-citizenship will be a win-win for them and India.

Recent research has thrown light on how to make the process of migration beneficial for both countries of origin and the destination; one of the suggestions offered is a pre-migration agreement for jointly financing the education and training of the migrants (Clemens, 2015). This might prove to be difficult since individuals can always have a change of plans regarding migration and when exactly to handpick migrants or provide them with the option to opt in, all pose tricky questions. Initiatives to ensure greater engagement targeted at scientists specifically, done with clear objectives in mind and implemented in a multidimensional manner, can reap great benefits.

The STEM diaspora, while contributing to global S & T, also contributes to the growth and development of STI in their homelands, particularly in new and emerging technologies. A study of the Chinese Diaspora and their contributions show that the Chinese diaspora contributed to the Chinese catching up in global science and science during 2000–2015 (Xie and Freeman, 2020). In the 1980s, Ireland formulated a series of policies for mobilizing diaspora contributions to Ireland in multiple ways resulting in inter alia, a larger inflow of FDI, and the promotion of tourism (Tian and Wu, 2016). Indian studies have established the positive contributions of diaspora and this could result in a win-win for the country of origin and country of destination (Buga and Meyer, 2012).

Apart from direct financial and intellectual contributions to developmental projects, their outreach to the citizens back home could provide valuable information on opportunities and access to their professional networks (Meyer and Brown, 1999); this can be utilized by NGOs and startups. Young minds can be broadened with the right kind of exposure and the inculcation of a scientific temper. The sharing of their experience would enable us to make desirable policy changes, particularly in our academic institutions so that we can provide the kind of institutional support the diaspora enjoys in more technologically advanced countries. This has been captured as "informational", "reputational", and "cultural" diffusion resulting from diaspora engagement (Paul, 2012).

Science diplomacy also becomes an opportunity for countries like India to take on the leadership in issues that really matter and thereby gain more respect and appreciation in the international community, particularly at a time when the superpowers have been hesitant to assume similar roles. At a regional level, it can provide a more compassionate leadership due to the understanding of Global South perspectives that it shares with its neighbors. India has already established the International Solar Alliance aimed at promoting solar energy worldwide and done its share in making COVID-19 vaccines available to the rest of the world. The expertise and networks of Indian-origin scientists can contribute greatly to such endeavors as well.

Over the years, the Government of India has initiated specific programs on using the expertise and skills of the STEM diaspora and engaging with them for mutual benefit (for details, see Initiatives in India section). This is done with an understanding that while they would work with institutions and initiatives, it would be a win-win situation. As we discuss elsewhere, these programs have been useful but not sufficient in terms of numbers or scope to make the best use.

Like many other governments, the Government of India has been enhancing its efforts for greater and better engagement and the recent PRABHASS is one such initiative (more details on https://www.prabhass.gov.in/). However, such efforts are to be seen in the context of Science Diplomacy (SD) to make the engagements more useful, dynamic, and meaningful. The section "Toward a New Model for Development: Linking Science Diplomacy and STI Diaspora" of the article proposes some approaches in this regard.

APPROACHES AND STRATEGIES IN USING DIASPORAS AND NETWORKS

"Diaspora networks—of Huguenots, Scots, Jews, and many others—have always been a potent economic force, but the cheapness and ease of modern travel have made them larger and more numerous than ever before. There are now 215 million first-generation migrants around the world: that's 3% of the world's population. If they were a nation, it would be a little larger than Brazil" (The Economist, 2011).

"Brain-drain" from India has attracted the attention of the government and other stakeholders since the 1970s. While, the negative connotation has, by and large, vanished, it is still a matter of concern, particularly the migration of students for education. According to the Organization for Economic Co-operation and Development (OECD), India has 3.12 million highly educated migrants. Although the number of Indians who gave up Indian citizenship has been increasing, the official contention was "no significant brain-drain to such an extent of affecting the developments in the science and technology sector" (Mohan, 2022). In the literature, we find many analyses that trace the causes of the "brain-drain" and its scope and how this could be translated into "brain gain" (Lavakare, 2013). But it is also contended that while considering the huge population migration is not a significant one and India has one of the lowest migration rates in the world (Sharma, 2021).

Irrespective of the number of migrants or the size of the Indian diaspora what matters is their contribution and how this contribution is changing in terms of diversity and sectors. For example, diasporas and diaspora networks are playing a key role in startups in India in more than one way (Varma, 2020). Indian diaspora all over the globe have formed many kinds of networks and thanks to the information revolution these have increased and expanded, and they serve more than one function.

Initiatives like TIE based in Silicon Valley have played a major role in the transfer of technology to the Information Technology Enabled Services (ITES) sector in India and through chapters have assisted young technologists in managing the hi-tech business (Raj, 2012). But these days, governments and states encourage diasporas to get engaged with the state/country and help in the transformation of the economy and transition to the knowledge economy. For example, a recent initiative in the Kerala state in India is broad viz. "The scheme seeks to identify experts in high-tech industries dealing with intangible assets and invite them for redesigning the higher education curricula and reorienting the research domain" (George, 2021). Kerala is also building a database on its diaspora and their expertise.

While, it is obvious that diaspora can contribute in many ways, it cannot be assumed that it will happen on its own; well-defined and consistent policies and programs are needed (Siar, 2013). But neither diasporas nor their networks can be assumed to be free-floating, which could be tapped at one's own will. In fact, as Craven (2021) points out "In conclusion, whilst social connectivity is important, networks of diaspora engagement do not float freely. They are embedded in global and local cultural fields, which in turn are embedded in a material environment".

STI policies are also paying attention to harnessing diasporas and their networks and want to integrate their plans for diaspora with overall STI policies trying to achieve more than one objective. and also link SD with this. For example, according to South Africa's white paper on Science, Technology and Innovation, "Properly leveraged, these 'brain circulation' networks could help drive innovation and knowledge generation in South Africa, and improve science diplomacy between countries" (Department of Science and Technology Government of South Africa, 2019).

However, the challenges are many including calibrating effective programs, identifying the right kind of networks to engage with and linking SD with these. In the literature on engaging with the STEM diaspora, the potential of SD is barely acknowledged and vice versa. Moreover, there is not much literature on linking SD, STEM diaspora, and SDGs or emerging technologies. In this article, we address the three pointing out that India can and should leverage SD and STEM diaspora for achieving SDGs and use them in harnessing emerging technologies. We suggest that to achieve this, India needs a new approach and strategy that goes beyond traditional approaches in engaging with the STEM diaspora or using SD.

Global Experience and Indian Experience in Engaging With STEM Diaspora and Science Diplomacy

Science diplomacy involving diaspora can go beyond merely reaching out to them or creating a common platform. It becomes imperative to look at the diaspora-oriented initiatives of other countries, particularly of those with similar socioeconomic conditions to improve our own. As UNESCO Science Report (2021) points out many countries have initiated different types of programs for engaging with the STEM Diaspora. While their scope varies, most of them are part of national STI policies/strategies (UNESCO Science Report, 2021).

Mexico is often described as the pioneer of diaspora engagement in Latin America. The 1991 initiative to repatriate emigrant researchers succeeded considerably with 1,859 researchers having been brought back and retained within 6 years from countries like the United States, Canada, Spain, United Kingdom, and Germany (Tigau, 2018). A network of scientists living abroad was also created in 2002 (Tigau, 2009). Repatriation efforts have also been successful in countries like Singapore, China, and Korea where they could create the infrastructure and network to accommodate the returnees (Meyer and Brown, 1999). Financial subsidies, special schools for kids, preferential treatment in the allocation of positions, and higher salaries were some of the key incentives offered to the returning scientists (Zweig, 2008).

However, not all countries can afford to make investments of this scale; a different approach would be to assume that most of the diaspora would not return and to convert the already existing "sporadic and limited" networks into "multiple, dense and systematic" (Meyer and Brown, 1999). The advantage is that it makes use of the already existing infrastructure and enables availing of the social networks created by the individuals abroad, especially in a professional capacity (Meyer and Brown, 1999); this comes in handy as the willingness to collaborate and trust is advanced by familiarity. China's recent strides in academic research have been attributed to the linkages with its diaspora who increasingly cite papers from China and are cited by domestic researchers (Xie and Freeman, 2020).

The total number of diaspora knowledge networks identified by a 1999 UNESCO paper was around 41 and had been classified into the five categories of "student networks", "local associations of skilled expatriates", developing and fully formed intellectual/scientific knowledge networks, and "pooling of expert assistance" through networks like the UNDP-initiated TOKTEN (Meyer and Brown, 1999). TOKTEN stands for Transfer of Knowledge through Expatriate Nationals and allows experts to return to their country of origin for a 2-week to three-month visit where they could assist with the local development issues.

Other well-known networks employed in science diplomacy include the Network of Arab Scientists and Technologists Abroad (ASTA), Argentina's PROCITEXT, Colombian Network of Researchers and Engineers Abroad, Iranian Scholars Scientific Information Network, Irish Research Scientists Association, Latin American Association of Scientists (ALAS), Peruvian Scientific Network, Tunisian Scientific Consortium, and Moroccan Association of Researchers and Scholars Abroad (Meyer and Brown, 1999).

Brazil started by mapping its diaspora and organizing events for celebrating and honoring them; this later grew into addressing specific issues faced by the nation (Maastricht Centre for Citizenship Migration Development, 2021). Such a focused approach is very pertinent from a developing country's perspective. India has seen the involvement of PIOs in projects employing artificial intelligence to solve issues in agriculture and healthcare; coordination on the part of the government would reduce costs and remove the obstacles dissuading diaspora from active engagement currently. This would demand behavioral changes on the part of the diaspora and institutional changes in the country of origin; a connection with the homeland and the genuine desire to solve its developmental issues would have to be inculcated in the minds of the diaspora and bureaucracy back home would have to be streamlined to facilitate diasporic intervention and to create an attractive work environment. A centralized top-down approach would have to be abandoned so that all stakeholders can offer suggestions and a system that is convenient for everyone evolves (Gaillard et al., 2017). This involves multidimensional change and cannot be achieved within a short time.

Paul (2012), while exploring the return of elite expatriate scientists to China, Singapore, Taiwan, and India, identifies funding, administration, network, staff and infrastructure as "elements of the scientific research system" and attitudes toward knowledge, approach to problem-solving, the scope of research ambitions, autonomy, the importance given to seniority and rank, way of communication and approach to differences of opinion as "elements of research culture", that had to be altered to improve productivity. Governments often focus only on making the research system similar to where the scientists come from, but there is a great scope for mutual learning in a cultural sense as well, demanding an open-mindedness toward new ways of learning and doing things that may organically emerge (Paul, 2012). Something seemingly minor as the reluctance of research scholars to propose a new idea to their supervisors reflects issues with the prevailing academic culture and Indian researchers are shown to have benefited from cross-cultural interactions (Paul, 2012). The ideas, values, and perspectives that the diaspora brings, dubbed "social remittances" by sociologist Levitt (1998), assume significance in this light.

This kind of cultural change can be brought about only in the long term and not merely through programs specifically aimed at science diplomacy. A higher degree of autonomy for research institutions and a freer academic culture help academics become "unintentional diplomats" (Sutton and Lyons, 2014). The private sector, intergovernmental organizations, and civil society actors including alumni networks can step in by facilitating dialogue between multiple scientific communities and creating platforms for collaboration.

The lack of coordination among different actors is a key issue faced by our SD initiatives. Spain has set an excellent example on this front through collaboration between the Ministry of Foreign Affairs and the Ministry of Science and Innovation and between two public agencies CDIT and FECYT (Morena et al., 2017). Scientists with an impeccable understanding of the research landscape in both the host country and Spain are appointed in Spanish embassies to lead the diaspora outreach activities and to foster cooperation between both scientific communities; the already existing diaspora networks had also provided a firm foundation to this initiative (Morena et al., 2017).

Traditional understanding and use of SD stems from state-centric and institutional-centric perspectives. While, there is nothing wrong *per se* with such perspectives, they are not adequate for harnessing the full potential of SD in engaging with Diaspora. A major issue with such perspectives is that they mirror a top to down approach with little scope for a bottom-up perspective. On the other hand, in Climate Change we find that while state-centric science diplomacy is flourishing, there are other developments such as city diplomacy (Bouchet, 2021). In the case of Science Diplomacy also there have been similar developments. According to the S4D4C Project, "New actors become visible in science diplomacy, sub-national regions and cities take charge of addressing global challenges and establish international relationships to exchange experiences and strengthen their profiles" (S4D4C, 2021). Barcelona's Science Diplomacy initiative is a good example of this (Roig et al., 2020).

Cities and sub-national entities may not be as powerful as the states are but they are part of the problem and part of the solution also. For example, while a state may not have a net-zero plan that addresses the climate change issue adequately, a city can draw a road map for a net-zero transition that is quicker and more effective. In the case of STI and engaging with diaspora as we have pointed out, there are initiatives that involve diaspora networks, and formal and informal associations. Initiatives like Global Honduras try to mobilize multiple stakeholders and develop a common agenda and platform for them.

Initiatives in India

India accounts for one of the largest Diaspora communities, numbering more than 18 million according to the United Nations Department of Economic and Social Affairs (Menozzi, 2021).

In the Indian context, the STIP diaspora has been instrumental in building technology-intensive sectors like information technology and biotechnology. Needless to say, with rapid technological advancements and the advent of the fourth industrial revolution, there is a need to harness the untapped potential of the STI diaspora to realize technological self-reliance and achieve sustainable development goals. India's IT sector has witnessed an exponential boom due to in cross-pollination of ideas and transfer of technological capabilities, wherein the Indian diaspora had been a major driver, in this context.

Efforts are being made by various stakeholders, including the government and private sector to harness the potential of the STI Diaspora in advancing and promoting scientific advancements, at national and international levels. This section reflects on some of the prominent practices to engage with Indian STI Diaspora.

Government-Led Initiatives

Developing countries like India have built their STI ecosystem by enhancing their technological capabilities. To promote cross-border technological learning and knowledge sharing, the government has developed various schemes and fellowships to encourage STI Diaspora for participating in national science, research, and development. One such initiative is the *Ramanujan fellowship* (Science and Engineering Research Board SERB, 2019), under the Department of Science & Technology, Government of India. The objective of this fellowship is to engage with Indian scientists and engineers residing in foreign countries and provide them with research positions in India. In 2019-20, 22 fellowships were recommended; some details regarding the fellowship are provided in **Table 1**.

The Department of Biotechnology, Government of India, introduced a similar scheme known as the "Ramalingaswami Re-entry Fellowship" for Indian Nationals, working overseas in biotechnology and life sciences domains who are interested to undertake research positions in India. The fellows are also eligible for regular research grants through extramural and other research schemes of various S&T agencies of the government. In 2021–2022, 88 Ramalingaswami re-entry fellowships were supported by the Department of Biotechnology (Department of Biotechnology, 2021). Various other schemes and fellowships are introduced by the government to engage with STI Diaspora for building scientific prowess at national and sub-national levels. A list is provided in **Table 2**.

TABLE 1 | Summary of Ramanujan fellowship (2019–2020).

Broad subject area	Number of ongoing awards	Number of awards sanctioned during 2019–20	Number of project completed during 2019–20
Chemical sciences	35	2	3
Life sciences	49	4	1
Physical sciences	51	2	2
Mathematical sciences	8	0	0
Engineering sciences	20	0	1
Earth and atmospheric sciences	7	1	1

Source: SERB, 2019.

TABLE 2 | Fellowships and schemes for Indian researchers residing in foreign countries.

Srl. No.	Name of the fellowship/scheme	Description
1	Visiting Advanced Joint Research (VAJRA) Faculty Scheme	This Scheme is to bring overseas scientists and academicians including Non-resident Indians (NRI) and Overseas Citizen of India (OCI) to India to work in public funded Institutions and Universities for a specific period of time. The scheme offers adjunct / visiting faculty assignments to overseas scientists including Indian researchers to undertake high quality collaborative research in cutting edge areas of science and technology with one or more Indian collaborators.
2	Ramanujan Fellowship	This Fellowship provides attractive avenues and opportunities to Indian researchers of high caliber, who are residing abroad, to work in Indian Institutes/Universities in all areas of Science, Engineering and Medicine. It is directed to scientists and engineers below the age of 40 years, who want to return to India from abroad.
3	Ramalingaswami Re-entry Fellowship	The program is to encourage scientists (Indian Nationals) working outside the country, who would like to return to the home country to pursue their research interests in Life Sciences, Modern Biology, Biotechnology, and other related areas.
4	Biomedical Research Career program (BRCP)	This program provides opportunity to early, intermediate and senior level researchers to establish their research and academic career in Basic biomedical or Clinical and Public Health in India. These fellowships are open to all eligible researchers who wish to relocate or continue to work in India.
	Scientists/Technologists of Indian Origin (STIO) in Indian Research Laboratory	There is a provision to appoint Scientists/Technologists of Indian Origin (STIO) on a contractual basis at Council of Scientific and Industrial Research (CSIR) laboratories to nurture a research field in their area of expertise.
5	Senior Research Associateship (SRA) (Scientist's Pool Scheme)	This scheme is primarily meant to provide temporary placement to highly qualified Indian scientists, engineers, technologists, and medical personnel returning from abroad, who are not holding any employment in India. The Senior Research Associateship is not a regular appointment, but is a temporary facility to enable the Associate to do research/teaching in India while looking for a regular position.
6.	Distinguished and Outstanding scientists scheme for the Scientists and Technologists of Indian Origin	A scheme by CSIR to engage global Indian S and T experts in the organization's activities which focus on shaping a new S and T landscape in India, to address global scientific challenges.
7.	Initiatives of Homi Bhabha National Institute (HBNI)	In this scheme scientists belonging to Indian S and T diaspora may be invited as visiting faculty members to some of the Constituents Institutes (Cis) of Homi Bhabha National Institute. Foreign students can be admitted to any of the five of the constituent institutions of HBNI viz. National Institute of Science Education and Research (NISER). Institute of Physics (IoP), Bhubaneswar, Saha Institute of Nuclear Physics (SINP), Kolkata, Harish-Chandra Research Institute (HRI), Allahabad, and Institute of Mathematical Science (IMSc), Chennai.

Academic Institutions

To develop indigenous technological capacities, it is important that the sites of academic learning and scientific research promote brain circulation and leverage on capabilities of Indian scientists and researchers residing in foreign countries. To realize this objective, some academic institutions have initiated programs to involve STI Diaspora for capacity building, networking, and mentorship. The alumni association of IIT Madras has envisaged a mentorship program to kick-start the activity. Over 5,000 alumni in 15 countries participated to celebrate the institution's foundation day in 2021 for short lectures on various themes including cutting-edge research and technologies, quantum computing, and extra-terrestrial manufacturing, to name a few (The Hindu, 2021).

Similarly, the IIT Kharagpur Alumni Foundation in the United States has been aggressively promoting student internships of IIT Kharagpur students in foreign institutions for career development as well as to enhance their technological capabilities. It has also led to exposure and learning for Indian students in some world-class academic and research institutions (Basu, 2019).

Some of the institutions are reorienting their recruitment policies to increase the intake of faculty members belonging to the Indian STI Diaspora community. For example, SRM institute has plans to increase the number of NRIs/PIOs among foreign faculty (source: https://www.srmist.edu.in/aboutus/panel-foreign-faculty) (SRM University, 2022).

Private Sector

Some private sector companies are also creating avenues to promote linkages with STI Diaspora. Internships are offered by various companies to engage NRI students on projects related to research and development (DNA India, 2016). Consortia like FICCI have been actively involved in events related to the Indian Diaspora, particularly the *Pravasi Bharatiya Diwas,* which are potent avenues to initiate dialogues for collaborations and engagements in STI.

Other Interventions

Collaborative efforts of various stakeholders and interventions by non-state actors are also coming into play to collaborate and engage with the Indian STI Diaspora. For example, the Wadhwani AI and WISH foundation are platforms founded by Indian-American technocrats to develop AI solutions for healthcare that are available and accessible for developing countries.

Project Madad, an initiative started by a voluntary group of doctors and professionals from the Indian diaspora in the United States, aims for "proper education and training" of local healthcare workers and registered medical practitioners (RMPs) particularly to manage and respond to the COVID-19 outbreak in rural India (Reuters, 2021). Initiatives like the "India Science Festival" and even Vaibhav Summit open up opportunities to engage and collaborate with Indian scientists and researchers abroad and build linkages with Indian counterparts. These activities have invigorated the dialogue for cross-border technological learning and knowledge sharing (Aggarwal, 2019).

While, there is ample evidence to assert that India is actively encouraging engagements with the STI Diaspora, it is important to note that most of these initiatives are limited in scope and do not have any long-term vision or objectives. Another issue with them is they are not linked with any major initiative in STI or with any technology missions. A fundamental problem with these initiatives is there is no synergy among them and they are envisaged as "stand-alone" programs with a limited objective. It is true that they do help in capacity building but in terms of numbers or scope, these are woefully inadequate for long-term capacity building or institutions acquiring specialized capacity in one field. So, a good question is whether they are adequate to engage with the STEM diaspora or to induce their return to India. We think they are not.

However, for us, the larger problem is these have no linkage with Science Diplomacy and there is no connection between them and various global networks in STI or science academies or with professional associations of scientists and technocrats. As a result, these have become yet another routine activity in terms of fellowships and opportunities than as major attractors for STEM diaspora. Since they are based at and offered by different ministries/institutions/departments without any institution coordinating them or trying to develop a link among them, efforts seem to be fragmented, with each trying to address one need/component. On the other hand, a coherent mechanism that can deal with the needs of STEM diaspora without trying to make them go through these "*Procrustean Beds*" is what India needs. Given the conditions including age, and disciplines, these function like filtering devices rather than as facilitating doors.

Conspicuous by its absence in all these is Science Diplomacy. Although there is no official Science Diplomacy policy, India has extensive S&T collaborations and is part of big science initiatives. In addition, India is part of groupings like BRICS, QUAD (United States, India, Japan, and Australia) and BASIC. While, there is a strong STI component in the case of the first two, it is not so with BASIC.

Thus, although there are initiatives to engage with the STEM diaspora, these are not adequate and increasing the numbers of fellowships or expanding them is not sufficient, Instead what is needed is a new approach, a new policy, and a strategy.

TOWARD A NEW MODEL FOR DEVELOPMENT: LINKING SCIENCE DIPLOMACY AND STI DIASPORA

According to Varadarajan, historically the contribution of the Indian diaspora to the development of India's foreign policy has been limited as till the early-1990s, there was no meaningful engagement with the Indian diaspora Varadarajan (2015). So, it is no wonder that India did not have any credible strategy till then to engage with STEM diaspora and benefit from their expertise, etc. While, academics (Pande, 2017) have pointed that out newer forms of engagement with diaspora are in place, there is no coherent and comprehensive approach to engaging with STEM diaspora.

In recent decades, the Government of India has initiated many programs for harnessing the STEM diaspora and for enhancing opportunities for them. But most of them are stand-alone programs and initiatives that serve a narrow purpose. There is no integration or synergy with larger initiatives in STI such as national missions or with sectoral policies that have a strong STI component. While, the absence of an STI policy is a constraint, the larger issue is that of disconnect between SD and programs focusing on NRI/PIOs. There is no official policy on SD. But SD is evident in many instances ranging from Vaccine Diplomacy to the formation of ISA.

The beginning of India's Science Diplomacy can be credited with the APSARA reactor built in 1956 under India-United Kingdom Co-operation Agreement. Since the Science Diplomacy in nuclear technology has seen ups and downs, the 2005 agreement between India-United States on the civil nuclear program is an achievement for Science Diplomacy in India. There are many bilateral research centers based on bilateral cooperation in STIs. At the regional level, there are initiatives like Regional Integrated Multi-Hazard EarlyWarning System (RIMES) for Africa and Asia and The Indian Ocean Global Observing System (IOGOOS) (Goel, 2022). The International Solar Alliance is an international initiative led by India for the effective harnessing of solar energy and the development and adoption of solar energy technologies. India's vaccine diplomacy is a recent phenomenon, and under this, India successfully supplied vaccines to countries all over the world.

The draft STI policy of 2020 states "As for the engagement with Indian diaspora is concerned, the policy direction is to create a fine balance between attracting the best talent back home and creating facilitating channels for the diaspora to contribute to national development from wherever they are appropriate institutional mechanisms and suitable opportunities will be created to engage with the Indian diaspora more effectively" (Department of Science and Technology, 2020). In fact, it states nothing about linking SD with initiatives on NRI/PIOs. In this context, we argue that there is a need to think boldly and imaginatively by going beyond what is being done.

As of now, there is no quality data on STEM diaspora across countries in the world and country-wise data is important as it will help in formulating country-specific strategies. Country-specific strategies are important as they will consider unique features in the respective countries' National Innovation Systems and accommodate the science diaspora accordingly. This will help in developing better bilateral cooperation in STI between India and the other countries. Given India's large number of bilateral cooperation agreements in S&T, India should use Science Diplomacy to enhance their numbers and effectiveness. STEM diaspora can contribute to this and the Government of India can, in turn, with specific policies and programs, try to integrate STEM Diaspora into this.

About two decades ago, in a pioneering study, Khadria (2003) pointed out that there are many networks of STEM diaspora which are part of networks of Indian diaspora and highlighted the contribution of STEM diaspora to S&T in India. There is a need to revisit and study the current status of various networks with which STEM diaspora is associated and whether the current policies and initiatives are adequate to engage with them and tap their potential. In this, the Government of India can work with professional organizations such as Science Academies and various organizations representing scientists in different disciplines. With the involvement of Science Academies, etc., on one hand, and leveraging Science Diplomacy's potential to connect and engage with them on the other hand, better linkages between policies and these professional associations can be developed.

Given the size of India's NRI/PIO and their impact, the Government of India should expand the scope and size of the current ones, to begin with, and go for bigger initiatives that can enable better utilization of their talent and expertise and create a win-win synergy for both. In this, the Central and State Governments can join hands and launch initiatives on themes listed in the Concurrent List of the Constitution of India. For example, in Higher Education, using the expertise and skills of NRI/PIOs can go beyond what is being done now. However, before embarking on this, the following needs to be done:

(1) Consolidate by bringing programs/initiatives with similar/same objectives as a single program.

(2) Establish a single board/authority to deal with all programs in STI related to NRI/PIOs (except those related to admissions to courses).

(3) Examine whether the current programs are adequate in scale and impact vis a vis the STI policy under preparation.

(4) Take a comprehensive view of engaging with STEM Diaspora in all aspects including involving them in incubators and startups.

Regarding employment opportunities for STEM Diaspora, Li et al. (2019) point out that India lacks a comprehensive strategy to fulfill the needs of different forms of returnees nor offers a specific Talent Visa to facilitate their return. According to them, "In India, recruitment plans are skill specific and "pertain to" or "involve" occupations like scientists, technologists and medical personnel. To recruit highly skilled Indians in the diaspora more effectively, we recommend that Indian institutions adopt a more assertive strategy to reach out to talent overseas".

A more integrated approach, with collaborative efforts from the government and industry would make more effective use of diaspora knowledge networks and facilitate "brain circulation" (Li et al., 2019). Further, their analysis shows that China has programs that have been successful in meeting the objectives of facilitating and enhancing the recruitment of STEM Diaspora (Li et al., 2019). India can examine its policies, and based on a review and adoption/adaptation of successful models from other countries, it can enhance the opportunities to STEM diaspora and ensure that there are all-around benefits for both in the short-, medium-, and long-term. While, Science Diplomacy may not provide an explicit tool for this, the better use of Science Diplomacy in engaging with the STEM Diaspora can result in effective outcomes.

India has committed to SDGs and in achieving them much importance is given to STIs. India is also a pilot country in STI for SDGs Road Mapping. This is a global program involving five countries: Ghana, Ethiopia, Kenya, India, and Serbia. Serbia has better-integrated diasporas with STI policy and has a "Diaspora Cooperation program" under the Science Fund, which is a program for competitive research funding.

The importance of emerging technologies in achieving SDGs is too well-known to be stated here (United Nations, 2021). The success of scientists and technocrats of Indian origin in the ICT industry, AI, and other technologies is well-known. More importantly, the diaspora contributed significantly to the growth of the Information and Communication Technologies sector in India in many ways and ensured that it was a firm footing to meet the global challenges in that sector (Pande, 2014). NRI/PIOs heading mega corporates like Microsoft, Google, and Adobe are too known to be repeated here.

Second generation NRI/PIO scientists are active in many emerging technologies and applications such as bio fabrication (e.g., Ritu Raman of MIT). We have any number of students doing PhD or Post-Doctoral Fellows spread across the world in these fields. The Indian SD is yet to recognize the potential of these emerging leaders and their future contributions. It is because Science Counselors do interact with NRI/PIO scientists and technocrats, and they become yet another constituency/stakeholder in their work. But more is needed in terms of strategy to address the needs of this constituency and identify how their needs can be met while enriching/contributing to the development of emerging technologies in India.

Students, particularly doctoral and post-doctoral fellows can be considered stakeholders in Science Diplomacy and engaging with them and early career scientists can help in their involvement in Science Diplomacy and contribute to that. There are some good examples of this such as EURAXESS North America (Science Policy Exchange, 2018). Given the large number of students and post-doctoral fellows from India, making them stakeholders in Science Diplomacy is a good idea.

India should appoint Science Ambassadors and Science Evangelists who will go beyond what a typical science counselor would do. These Ambassadors and Evangelists can be chosen from scientists/technocrats or entrepreneurs. They will act as a bridge between the Government of India and the NRI/PIO diaspora and will focus on a particular region. It is also possible that the Ambassadors or Evangelists can work on broad disciplines and connect the NRI/PIOs with programs and initiatives. We illustrate this with an example. India has many programs and initiatives on AI and there is a national plan for AI.

There are also state-level initiatives on AI and other stakeholders such as industry, NASSCOM is working with state and central governments' initiatives. But if one looks at the existing programs or initiatives there is nothing specific that will engage with NRI/PIOs in this. This is because while there are programs and initiatives on NRI/PIOs, they are almost general/generic in nature without any specific orientation toward any specific technology or Technology Mission.

Simultaneously, the Technology Missions or related initiatives are specific in terms of objectives and goals but have no specific plan or role assigned to NRI/PIOs. A Science Ambassador or Evangelist can address this gap effectively by acting as a bridge among these. For example, in the case of the use of AI in school education, the Ambassador in San Francisco will map the available expertise among NRI/PIOs in the West Coast region and identify the scope for their engagement with relevant programs and initiatives. (S)he will develop a forum for continuous engagement of NRI/PIOs with relevant stakeholders and ensure that their expertise is understood and used. It is not necessary that an NRI/PIO should be fully engaged with such programs or initiatives. Given their expertise in that domain, they can guide the stakeholders in taking the right decisions including deploying the appropriate technology.

On the other hand, mapping the expertise will also help in identifying opportunities for startups and not for profit initiatives to contribute to such initiatives /missions. For example, a Science Ambassador focused on AI can work with the central government and state government in this. (S)he can enable them to get connected to relevant experts and can act as a bridge and catalyst. Although there are initiatives like developing databases on experts, and, these can be used by Technology Missions or state governments, databases or using them is not sufficient. What is needed is personal interaction and engagement with NRI/PIO experts and continuous attention to the developments.

Databases are often static and do not get updated nor can capture developments like an NRI/PIO getting a patent on a technology that is relevant for a mission. Updating them on a regular basis is one solution but that alone will not help. A Science Ambassador can bring in a personal touch and combine that with expertise and goodwill to make a real difference. (S)he can facilitate processes to move faster or enable quicker interaction.

But given the large number of NRI/PIOs on one hand and the limited resources available with Embassies and Consulates on the other, there will be real constraints. So, a Science Ambassador/Evangelist must be part of a larger strategy of engaging with NRI/PIOs and STI. That larger strategy should be embedded in the overall strategy on NRI/PIOs. It is here that SD can play a positive and effective role.

The traditional view of "Science for Diplomacy" and "Diplomacy for Science" is necessary but not sufficient because both Diplomacy and Science are not broadly construed in them. Concepts like Diaspora Diplomacy are useful and they have to be rethought in terms of Science Diplomacy and STI for Development. Similar to "Science for Diplomacy" and "Diplomacy for Science", there is "Diplomacy by Diasporas" and "Diplomacy through Diasporas" (Ho and McConnell, 2017). Ho and McConnell (2017) point out that "the transnational and scalar actions of diasporas point to the multi-directional aspects of diaspora diplomacy. This leads us to conceptualize diaspora diplomacy as diaspora assemblages composed of states, non-state and other international actors that function as constituent components of assemblages, connected through networks and flows of people, information and resources" (Ho and McConnell, 2017).

In recent years, diaspora diplomacy has attracted the attention of policymakers and academics and the literature on this is exploring inter alia, how diaspora diplomacy and public diplomacy can be linked and used (Rana, 2013). However, there is not enough literature on using diaspora diplomacy and Science Diplomacy together. The fluid nature of diaspora diplomacy can result in contentious outcomes and as often who constitutes the real and authentic diaspora and who cannot be considered so can be controversial. But in the case of linking Diaspora Diplomacy with Science Diplomacy, such a situation will not arise as the objective here is different and is focused on expertise, knowledge, and their usefulness than on identity politics or claims over identity. In issues like Climate Change, there are sub-national actors who have emerged and are addressing an issue of common concern by developing networks, sharing information, and building alliances that transcend national borders.

Diasporas can be compared with Janus. Just as in the case of Janus, they look in two directions, one is the direction of their origin and another is that of their location or place of flourishing. But they can remain "at home" in both places and link their country of origin and their country of work/doing business. According to Burns (2013):

"In the United States, a quarter of foreign-born workers with college degrees work as scientists or engineers. According to a report by the Kauffman Foundation, foreign-born entrepreneurs started a quarter of U.S. technology startups over the past six years. In Silicon Valley alone, 44 percent of these engineering and technology ventures were founded by at least one immigrant. As of 2010, one-third of the 314 laureates who won their Nobel Prizes while working in the United States were foreign-born."

While, this shows the importance of diasporas, organized diasporas with their collective expertise, networks, and linkages can play a key role in linking diaspora diplomacy and Science Diplomacy in both countries. For this, we need to think beyond state-centric and science institutions-centric Science Diplomacy and think in terms of new constellations, collectives, and assemblages. For example, Diaspora Diplomacy combined with Science Diplomacy can result in developing a mechanism for connecting STEM diasporas based in Silicon Valley with a particular state that wants to utilize their expertise in solar energy or renewable energy and integrate that with its energy and climate change plan. In this case, only a section of the STEM diasporas will be involved with that state. But such an engagement can be part of the state-level Science Diplomacy strategy which may or may not have linkages with the national-level one. What is true of solar energy or renewable energy can be true of AI.

At another level, this can be linked with state-level SDGs also in this case SDG 7, i.e., affordable and clean energy. The engagement can have different components including capacity building, investment, venture capital, transfer of technology, and supporting startups.

The approach we propose envisages the following:

- Broadening of Science Diplomacy in terms of approach and strategy.
- Involvement of stakeholders including states.
- Linking Diaspora Diplomacy with Science Diplomacy with a focus on STI, SDGs, technology Missions, and other goals/objectives.
- Creating new institutional structures, networks, and assemblages.
- Specific engagement with STEM diaspora including their networks, associations, and resources.
- Developing a coherent policy and strategy that creates an enabling environment for effective use of and engagement of STEM diaspora.

Science Ambassadors or Evangelists will be part of this proposed structure. But in the absence of a supportive environment and institutional arrangements, they cannot do much. The supporting environment has to be created through the strategy while institutional arrangements have to be made. These can be built upon the available ones or can be new initiatives. For example, in addition to traditional professional associations and networks, there can be Associations of NRI/PIO like professional associations. An association of NRI/PIOs engaged in solar energy can bring together stakeholders of different kinds including entrepreneurs and scientists. The association can support the work of Science Ambassador or Evangelist on one hand, and, on the other hand, can engage with the state that is keen to harness their expertise, knowledge, and networks. The Science Ambassador can act as a connecting point or bridge among the other stakeholders. (S)he can link up with International Solar Alliance (ISA) and similar organizations. Given the increasing importance of renewables in decarbonization strategies and various bilateral and multi-lateral initiatives in this, using Science Diplomacy to build bridges and alliances can make a difference in translating plans into actions and achievable targets. India, for example, can have a Science Ambassador for Solar Energy, positioned strategically in countries like United States and China to facilitate developing alliances and networks. We are aware that this needs a detailed plan and that is beyond the scope of this article.

However, the problem here is that, although there are many diaspora associations based on different identities and for different purposes, there is hardly anything that is related to STI and development with the objective to work with different stakeholders in India and abroad through Science Diplomacy. Hence there is a need to relook at the current associations and networks of the Indian diaspora including the professional networks and associations. In the absence of any functional association or network, the Government of India, and other stakeholders can initiate the process of forming them. For example, an association of NRI/PIOs working on quantum technologies or an association of NRI/PIOs working on AI. In both cases, there are national-level missions/plans and state-level ones. But to have a focus on themes the association(s) can have sub-groups or working groups that can be linked with goals or specific programs. At another level, these associations can form a Federation of (such) Associations that will be a coordinating body that can play a larger role in the larger context of STI.

If India's Science Diplomacy policy and strategy must harness on STEM diaspora, it has to think in terms of new institutions, networks, and objectives. It needs a Mission-oriented approach. The role of the current programs and initiatives can be rethought considering the above discussion. For example, the development of databases of NRI/PIOs can be linked to that of forming associations and use of Diaspora Diplomacy by making NRI/PIOs key stakeholders in this, rather than as passive information sharers. They should have a role and say in developing and using them. Similarly, mapping of contributions of NRI/PIOs in terms of emerging technologies should be undertaken and this should include patents. When the contribution of NRI/PIOs in a particular field is mapped in terms of technologies and applications, it can be compared with technologies needed or expertise in demand in India or with the state of the art in India. Such an analysis will reveal the potential of NRI/PIOs to contribute collectively or individually to ongoing research or projects in India. In another way, this can relate to research problems or issues in adoption or commercialization. These exercises need much technical expertise and perhaps also involve inter-disciplinary research. They also need institutional structures and programs to do them continuously.

One major shift that is needed is that instead of relying on top-down Science Diplomacy, India should make effective use of bottom-up approaches in Science Diplomacy. In this regard, Spain's initiatives in giving support to bottom-up associations and the adoption of a multi-stakeholder approach have been effective (Morena et al., 2017). India can learn from such examples and develop a strategy that is commensurate with its objectives and resources.

In this article, we have outlined some of the possibilities and an approach that can be useful for Indian Science Diplomacy. Certainly, these need to be developed further and sharpened and our idea is to highlight the potential and possibilities. Developing them further is reserved for another occasion/opportunity.

CONCLUSION

Our analysis shows that although many initiatives have been taken by the Government of India to make the best use of expertise, knowledge, and connections of the STEM Diaspora, there is hardly any synergy or coherence among them. Nor are they linked with major initiatives or Missions or for that matter with SDGs. One reason perhaps is India has no specific and explicit policy on Science Diplomacy. Another could be that different ministries and departments are managing these initiatives with no central mechanism or agency to coordinate them. Not all initiatives related to diaspora need to have an STI component in them or be targeted toward STEM diaspora. But what is crucially missing is the policy and strategy on using Science Diplomacy for sustained and sustainable engagement with them. Some initiatives like the creation of databases and having dialogues with the STEM diaspora are important but the possibility of them getting stagnant or a routine affair cannot be ruled out. Science Counselors and attaches have an important role in engaging with STEM Diaspora but we have suggested that India needs "Science Ambassadors" and "Evangelists" for the specific purpose of engaging with STEM diaspora.

Based on the literature and examples from other countries and in other contexts, we have called for a new approach to using Science Diplomacy, going beyond the traditional state-centric Science Diplomacy and suggesting better linkages between diaspora diplomacy and Science Diplomacy. Science Diplomacy itself is changing and there is a strong case for "Data Driven" "Science Diplomacy 2.0" (Turchetti and Lalli, 2020). Our approach is that Science Diplomacy should use strategically the data regarding STEM diaspora going beyond the creation of and usage of NRI/PIO databases.

For effective harnessing of expertise, knowledge, and networks of STEM diaspora, India's Science Diplomacy policy and strategy should adopt a Mission mode approach and think in terms of developing relevant and new institutions and networks. Some aspects of this have been discussed and elaborated upon in this article. It is hoped that this will kindle new thinking on this subject among the experts and policymakers.

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The article has been conceptualized and planned by NP and KS. TD was involved in providing inputs to the arguments and organizing the article. All authors contributed to the article and approved the submitted version.

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Connecting Scientists Residing Abroad: A Review of *Converciencia* as a Practice to Engage the Guatemalan Scientific Diaspora From 2005–2020

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In 2005, the Guatemala National Secretariat of Science and Technology (Senacyt) introduced *Converciencia,* a program designed to connect Guatemalan scientists residing abroad with their country of origin. *Converciencia* has been a flagship practice for over 15 years. This program involves three main groups of participants: (i) science and technology (S&T) policy agents, (ii) the scientific community (including parts of the Guatemala scientific diaspora, GSD), and (iii) host institutions (local co-organizers, mainly universities, and research institutes). This article presents a comprehensive and balanced overview of the *Converciencia* program applying an in-depth analysis of its creation, evolution, leading trends, and legacies. Using a qualitative methodology and conducting a four-level analysis (descriptive, explanatory, normative, and prescriptive) allowed for the identification of nuances of this S&T practice in the context of a scientifically lagging country such as Guatemala. The detailed data collected through documentary and desk review, gray literature, focus group discussions, and semi-structured interviews resulted in a framework to highlight the strengths, weaknesses, opportunities, and threats (SWOTs) in the planning, organization, implementation, monitoring, and perception of the results achieved by *Converciencia.* Findings portray the contrasting views and perceptions from a single S&T practice, depending on the participating parties' roles and responsibilities. Direct participants examined how *Converciencia* has achieved its objectives while questioning the effectiveness and impact that the resources allocated to the initiative have yielded over time. Evidence indicates that despite the design, coordination, and evaluation limits of *Converciencia*, the GSD, the scientific community in Guatemala, and the host institutions are interested in the continuity of the practice. Indeed, the main recommendation involves restructuring and turning *Converciencia* into a robust S&T policy. *Converciencia* as a policy engaging the GSD could produce greater results and impacts by involving all the key actors in co-designing activities, clearly determining roles and responsibilities, and establishing performance and impact indicators for evaluation.

Keywords: science diasporas, S&T policy, S&T capacity building, Guatemala, *Converciencia*, brain drain-brain circulation, knowledge network diasporas, skilled migration

INTRODUCTION

The emigration of talented and highly educated individuals from developing to advanced countries has been of interest in literature for several decades (Meyer and Brown, 1999; Commander et al., 2004; Lewin and Zhong, 2013). Although the dominant paradigm has been brain drain (Commander et al., 2004), a shift in the narrative proposes a new approach toward brain circulation and the power of knowledge networks to enable those individuals to remain relevant to their country of origin (Meyer and Brown, 1999). Various studies have focused on the diaspora and how countries develop policies with their populations abroad (Davenport, 2004; Ragazzi, 2014). Different geographic contexts have explored the topic in their territories, such as China, India, and Russia (Li et al., 2019; Yurevich et al., 2019). However, limited research has addressed the emergence and engagement of scientific diaspora (SD) in the Latin America region. A recent study on the role of skilled migration in the Caribbean (Alleyne and Solan, 2019) has concluded that it is likely that skilled migration will continue and that developing countries must seek to benefit from such migration. The study also argues that diaspora networks can help stem the long-run migration of highly skilled workers, but this will depend on improving local conditions for those at home and those who may wish to return or collaborate through networks. In the last decade, "brain circulation" has taken further relevance *vis a vis* the traditional ideas of brain drain because of the growing mobility of talents across international boundaries (Tung, 2008). Guatemala requires a stable, effective, and long-term national S&T policy with valuable cooperation provided by the SD, partner countries, and international higher education institutions to turn brain drain into brain circulation (Bonilla et al., 2018). Other researchers have also referred to brain networking as a feasible methodology given the difficulties of reversing brain drain and creating brain circulation in developing countries (Ciumasu, 2010). The study of Ciumasu identified policy preference and implications for the systematic development of linkages between SDs and resident scientists creating brain networking. Valuable progress has been made in defining the problem and formulation of science, technology, and innovation. Still, the scope of the concepts concerning developing countries in the Central American region in the global context is pending (Viales-Hurtado et al., 2021). Expansion of the research agenda would strengthen the SD community's ability to inform policies for societal change, considering the "innate interest of the research community in innovation and development in activating change through public policy" (Lema et al., 2021, p. 1). There is an added value of network dependencies capturing political and cooperative interactions across countries (Kammerer and Namhata, 2018). The research by Kammerer and Namhata (2018) finds that adoption of climate policies is a matter of social influence. Governments are more likely to adopt policies if they cooperate with countries that have adopted more climate policies and are in a similar structural position to countries active in climate protection. Therefore, a similar approach could be taken to other science and development policies with the influence of the SD. In other words, public policies and practices engaging the GSD, including interactions across countries, are vital for contributing to the scientific communities in Guatemala.

From the policy perspective, some cases can be highlighted in the context of Latin America, particularly the cases of Colombia, Argentina, Mexico, Brazil, Uruguay, and Costa Rica. Chaparro et al. (2016) show that in Colombia, the Caldas Network is a case worthy of analysis, as it is a pioneer in the region. This initiative was created as *Red Colombiana de Investigadores en el Exterior R-Caldas* (Colombian Network of Researchers Abroad). It was founded in 1991 and managed by *Colciencias* (formerly Administrative Department of Science in Colombia, which is currently part of the Ministry of Sciences). Its purpose was to channel the research potential of Colombians living abroad to the country and link them to research institutions for the creation of scientific capacity. *R-Caldas* relied on connections among Colombian diplomatic missions abroad to identify and reach out to the Colombian SD. The engagement activities of the members of the *R-Caldas* were classified into four categories: (i) identification of research areas with possibilities of cooperation and formulation of joint projects, (ii) training of human resources and return of researchers, (iii) internships and mobility, and (iv) communication and scientific dissemination. In Argentina, *Programa Raices* (a network of Argentine researchers and scientists) was designed by the Ministry of Science, Technology, and Productive Innovation in 2003. It became a national policy in 2008 managed by the National Agency for Scientific and Technological Promotion and the National Council for Scientific and Technical Research. The objectives included permanent or temporary repatriation of Argentine researchers residing abroad, development of networks linking local researchers and those of the diaspora by realization of short stays, dissemination of job opportunities agreed upon with the private sector and foundations, and dissemination of scientific and technological activities (Charreau, 2011; Luchilo, 2018). The program is still actively pursuing four lines of action: (i) acknowledgment and repatriation, (ii) strengthening of research capacities in Argentina, (iii) engaging Argentinian scientists residing abroad, and (iv) sharing opportunities for career progression. In Mexico, the program *Red de Talento Mexicano* started in 2000 under the Network of Mexican Talents Abroad as a result of spontaneous actions from individuals who later received official support from the Government of Mexico. Since 2013, the network has been known as Red Global MX. Currently, it is managed by the Ministry of Foreign Affairs and the National Council for Science and Technology. Initially, it was focused on Mexican scientists residing in the United States of America to promote the integration of Mexico into the global knowledge economy through scientific dissemination events, academic cooperation, and linkage projects with strategic sectors. Currently, Red Global MX has a portfolio of more than 180 projects that link its members directly with Mexico and help promote the name of Mexico abroad. It is organized through local chapters located in four regions worldwide: the United States and Latin America, Canada, Asia-Oceania, and Europe. It consists of 58 chapters in 28 countries and has more than 6,500 members (de la Barrera Soria, 2011; Red de Talentos Mexicanos, 2020). In the case of Brazil, Carneiro et al. (2020) analyze the case of

Rede Diáspora Brasil (Brazilian Diaspora Network), a project developed between 2013 and 2016, as a series of engagement strategies related to the Brazilian diaspora of science, technology, and innovation promoted by the Brazilian government. This project was designed and implemented by the Brazilian Industrial Development Agency (Abdi) and was funded by the Brazilian Trade and Investment Promotion Agency (Apex-Brasil). The project aimed to set up a "network of networks," engaging active initiatives and Brazilian professionals (executives, entrepreneurs, and scholars) and foreign professionals with ties with Brazil. Some of the project's main components included building partnerships and research cooperation to develop business and projects in intensive knowledge and technology areas. The case of Uruguay involves the program *Circulación de Uruguayos Altamente Calificados* (Circulation Program for Highly Qualified Uruguayans, CUAC). The program was created in 2005 to "actively and effectively link highly qualified Uruguayans residing abroad with national institutions" (Ministerio de Relaciones Exteriores, 2022, p. 1). This was sought primarily through innovation projects and the promotion of national capacities and knowledge transfer (Taks, 2006). Finally, in the Central American region, Costa Rica presents the case of *Hipatia* (Santos Pasamontes, 2022). This program was created in 2014 and managed by the National Council of Rectors to provide an updated overview of the country's science, technology, and innovation capabilities to support public-private decision-making. Though this program, by bringing together the supply and demand for technology and qualified human resources through the *Hipatia* portal, professionals in the diaspora have been identified in more than twenty science and technology (S&T) disciplines. The diversity would facilitate communication between colleagues to implement collaboration mechanisms in multiple fields. Several of them intersect with aspects related to the country's development process.

In the case of Guatemala, there are no studies focused on the engagement of the Guatemala Scientific Diaspora (GSD) or significant policies addressing the relevance of the migration of skilled individuals and the eventual connection among them and with their country of origin. This research intends to bridge such gaps. This article presents a comprehensive review of *Converciencia* as the single identified initiative designed and implemented by the Guatemala National Secretariat of Science and Technology (Senacyt) aimed at connecting Guatemalan scientists living and working abroad with their country of origin. This initiative has incorporated the participation of grassroots actors, including members of the GSD and host institutions (co-organizers). *Converciencia* has also mobilized broader sectors of the society, such as the media, the industry/productive sector, other public institutions, organizations from the civil society, and students in middle, high school, and universities. *Converciencia* has used valuable and scarce human and financial resources, which should be analyzed against the achieved results. The review of this S&T practice follows a four-level analysis adapted from Patton et al. (2013, p. 31) that is: (i) descriptive, (ii) explanatory, (iii) normative, and (iv) prescriptive. In addition, the SWOT (strengths, weaknesses, opportunities, and threats) method was applied to enhance the discussion while incorporating the perspectives of the parties directly involved in the organization/implementation of *Converciencia* each year. The SWOT method has been historically used as an organizational tool for strategic planning (Gurel and Tat, 2017). This tool allowed for highlighting the limitations reported by stakeholders and participants. Finally, as part of the prescriptive analysis, participants also propose actionable recommendations to improve *Converciencia*. This article provides readers with the first comprehensive overview of activities, involved actors and stakeholders, resources invested, results, and lessons from *Converciencia* as an S&T practice to engage the GSD for over 15 years.

METHODS

This study was carried out using a qualitative methodology in which three types of methods were used to collect data: (i) focus group discussions, (ii) semi-structured interviews with key respondents, and (iii) documentary and gray literature review. Primary and secondary data were collected to incorporate the perspectives of the three main parties involved in *Converciencia* since its origin.

Table 1 summarizes the participants in the study who provided data from the policy perspective. The first group comprises all individuals who have occupied the National Secretary of Science and Technology position in Guatemala during the study period (**Table 1**).

The second group of participants provided a perspective from the Guatemala scientific community, mainly members of the GSD who have participated in one or more editions of *Converciencia*. This category emphasized the selection criteria (see **Tables 2**, **3**). Diverse representation was sought in terms of gender balance, fields of knowledge, stages in their career, and the country/location of the destination. From semi-structured interviews, nearly 30 h of audio material was collected from the application of semi-structured interviews and focus group discussions. Each interview session had an average duration of 45 min, while the focus group discussions lasted for 60 min.

From a preliminary list of 40 potential key respondents, a total of 14 participated in two focus group discussions.

As for host institutions, five co-organizing partners of *Converciencia* were selected based on their relevance to the program's science and research capacity-building component. **Table 4** below summarizes the selected participants.

In addition, the authors developed a body of gray literature for review using annual reports from Senacyt from 2005 to 2020. This was complemented by media coverage and published news related to *Converciencia* during the period of the study. In addition, we reviewed the public records of the meetings from the International Network of Science, Technology, and Innovation (*RedCTI*). The review of relevant literature contributes to a deeper understanding of the policy and practice analysis. Complete details of the participants can be found in the supplementary data. Following data collection, a multi-layered policy analysis was conducted.

TABLE 1 | Participants from the policy perspective: secretaries of science and technology in Guatemala (2005–2020).

Secretary	Period	Profile summary (education and occupation)
Rosa María Fabian Amaya	2005–2008	Economist—Usac (Guatemala), Master in Operations Research Ufm (Guatemala), Doctor in Research Sciences (Umg (Guatemala)/Professor at Usac School of Economic Sciences
	2009–2012	
Miriam Rubio Contreras	2013–2014	Industrial Engineer—Usac (Guatemala). Institutional Projects Advisor to the Rector, Usac Consultant and Technical Advisor Intecap. Professor, Usac
Armando PokusYanquián	2014–2016	Civil Engineer from Usac and Project Manager and magister from Umg. Investment project management consultant with experience as Professor from local universities
Oscar Cobar Pinto	2016–2019	Pharmaceutical Chemist from Usac, Doctor in Chemistry specializing in Organic Chemistry, University of Puerto Rico. Usac Professor and Former Dean of the Faculty of Chemical Science and Pharmacy, Former Director of Research DIGI Usac
Ana Judith Chan	2020–incumbent	Lawyer, Master's in International Business Law from the *Pontificia Universidad Católica de Chile*. Former President Guatemalan Mexican Chamber of Commerce and Industry (Camex)

Source: based on public records and available public information from the participants. Usac, San Carlos of Guatemala University; Ufm, Francisco Marroquin University; Umg, Mariano Galvez University; Intecap, Institute of Technical Training and Productivity; DIGI, Directorate of Research.

TABLE 2 | Criteria for participant selection: focus group discussions, Guatemala scientific community.

Criteria	Description	Operationalization
Experience	Experience in community building or participation, networking, groups of scientists	Reporting experience in building and/or participating
Trajectory	Procure diversity in the representation of career development stages of the interviewees (early and mid-established career).	Years since completion of graduate studies. Early <10 years, Mid +10 years but no management positions or group coordinators. Established +15 years in addition to management or research group coordination positions
Field of expertise	Diverse fields of knowledge (i.e., natural sciences, health, earth science, social sciences, physics, and engineering sciences)	All fields of knowledge were considered, including social, natural, and engineering sciences
Destination diversity	Covering a wide range of geographic locations for destinations.	Including as many geographic destinations as possible region/country, i.e., North America, Europe, Asia, and Latin America
Gender balanced	Balanced participation of women and men	Gender equality in participation.

RESULTS AND DISCUSSION

This section presents the discussion and findings following a four-level policy and practice analysis. **Table 5** summarizes descriptors, questions for operationalization, and perspectives in each level of analysis.

Descriptive Analysis

This level of analysis refers to the general characteristics of the practice. It includes the most relevant features, namely, vision, parties involved, roles and responsibilities, and resources. It is essential to include the perspectives reported by all the parties involved.

Converciencia as an S&T practice has taken place for over 15 years. One of its main objectives has been to connect the GSD with local scientists, the industrial sector, the academic community, and society. Institutions from the public sector involved in organizing *Converciencia* include the National Council for Science and Technology (Concyt) and Senacyt. Other institutions with indirect involvement in different editions have included the Ministry of Education, the Congress of Guatemala, and the Technical Training and Productivity Institute (Intecap). From the scientific community, the main representation has been the *RedCTI*. However, researchers and scientists working in local universities and research centers have also been part of *Converciencia* activities. Host institutions co-organizing *Converciencia* have mainly included those with presence in the capital city of Guatemala. However, in various editions, host institutions have participated in co-organizing/hosting *Converciencia* in a few departments (provinces) of Guatemala. Other actors with sporadic participation include international organizations, non-governmental organizations, and industry and private firms. In this level of analysis, it is crucial to describe the involvement of the main actors and stakeholders that have consistently participated in *Converciencia.* **Figure 1** illustrates the diversity of actors and resources that this S&T practice

TABLE 3 | Participants from the scientific community, Guatemala scientific diaspora (GSD): two focus group discussions.

Stage in career	Country of residence or experience as GSD	Gender balance	Research area
Group A: scope: pro-*Converciencia*			
Established career	Chile	M	Electronic engineering/wireless communications
Early-Career	Taiwan	F	Biomedicine/nanotechnology
Mid-Career	Sweden	F	Water studies/limnology
Established career	Spain	F	Health sciences/virology
Mid-Career	United States	M	Mathematics/mathematical physics
Established career	United States	M	Physics/gravitation and numerical relativity
Established career	Germany	F	Environmental sciences/water bioindicators
Group B: scope: critic: *Converciencia*			
Mid-Career	Chile	M	Social sciences/science communication
Early career	Costa Rica	F	Biology/endemic species and conservation
Established career	Spain	M	Molecular biology/biotechnology
Established career	Spain	F	Chemical sciences/toxicology
Mid-Career	United States	F	Medical and health sciences/neurosciences
Established career	Canada	F	Food and nutritional sciences/iron safety studies
Established career	Germany	F	Public health nutrition/meal patterns in school children

N = 14, F, Female (N = 9); M, Male (N = 5).

has mobilized over time. The variety of actors mobilized and resources used in the context of *Converciencia* are illustrated in different colors, nodes, and veins.

The National Secretariat for Science, Technology, and Innovation (Senacyt)

Concyt formulates the country's science, technology, and innovation policy. It aims to direct and coordinate the national scientific and technological development with the executing functions of Senacyt (Jarquin-Solis and Mauduit, 2021). Concyt is chaired by the Vice President of Guatemala and has nine members: the Minister of Economy, the President of the Commission of Science and Technology from the Guatemalan Congress, one representative of the Chamber of Industry, one representative of the Chamber of Agribusiness, one representative of the Chamber of Commerce, the Rector of the San Carlos of Guatemala University (Usac), one Rector representing the private local universities, and the President of the Academy of Medical, Physical, and Natural Sciences of Guatemala. Senacyt executes and implements the policies and decisions of Concyt and constitutes the link between institutions that form the National System of Science and Technology (Sincyt). The Decree 63–91 Law created Sincyt for the Promotion of National Scientific and Technological Development, which constitutes the general framework for orienting scientific and technological activities in the Republic of Guatemala.[1]

Senacyt is the government institution that, in response to a mandate by Concyt, designed *Converciencia* and has kept the role of principal organizer of the annual event since its creation in 2005. A comprehensive review of all the available annual reports issued by Senacyt in the study period (2005–2020) provides a detailed summary of the main highlights of *Converciencia* reported each year. **Table 6** summarizes the number of times *Converciencia* is referred to each year. Interestingly, some patterns emerge in terms of the absence of performance indicators and difficulties in conducting a comparative/monitoring analysis. Also, a period with no activities related to *Converciencia* was confirmed from 2013 to 2016.

The Scientific Community and the International Network of Science, Technology, and Innovation of Guatemala *(RedCTI)*

In 2005, with the framework of the first *Converciencia*, *RedCTI* was founded. This was promoted by the National Secretary of Science and Technology, the Presidential Commissioner for Science and Technology, eleven members of the SD of Guatemala, and eight scientists residing in Guatemala representatives of the Council of Notables (awardees of the National Medal of Science and Technology, the highest recognition for scientific work in Guatemala). The main objective of this network was to generate academic coordination between different Guatemalan institutions and to engage Guatemalan scientists with *RedCTI*. Also, part of its goals was to identify academic content of diffusion, teaching, research, innovation, science communication, and knowledge transfer for the development of Guatemala. *RedCTI* constitutes one of the main actions supported by Senacyt to promote S&T for national

[1] See https://www.senacyt.gob.gt/.

TABLE 4 | Selected host institutions: perspective for local partnerships for capacity building.

Code for references	Institution	Department	Relevance
Host Institution 1	Universidad de San Carlos de Guatemala Usac	Faculty of Chemical Sciences and Pharmacy Faculty of Engineering	Usac is the only public University in the country. It is responsible for directing, organizing, and developing higher education in Guatemala One of its missions is to promote research in all spheres of human knowledge and cooperate with actors in the national innovation system to produce responses to national needs The academic units included in the study have participated in various editions of *Converciencia* A significant group of the GSD has obtained their undergraduate degrees in this University from these academic units. The Faculty of Chemical Sciences and Pharmacy designed and ran a joint doctorate program initiated through *Converciencia* between Unam and Usac
Host Institution 2	Universidad del Valle de Guatemala Uvg	Directorate of Research *Centro de EstudiosAtitlán CEA*	Uvg is the leading private University in Central America and Panama by QS Ranking 2022 This University employs prominent local established researchers who have partnered with *Converciencia* Uvg participated for several years as a *Converciencia* host institution A significant group of members of the GSD had obtained their undergraduate degrees from Uvg and kept collaborating with local researchers at Uvg
Host Institution 3	Universidad Galileo Ugal	School of Electronic Engineering	Ugal participated for several years as a *Converciencia* host institution Ugal has achieved research cooperation through *Converciencia, resulting* in international publications
Host Institution 4	Universidad Rafael Landivar Url	Incyt Institute of Science and Technology Iarna Institute of Agriculture, Natural Resources and Environment	Url participated as a *Converciencia* host institution in various editions The Guatemalan Institute of Agriculture, Natural Resources and Environment of the Rafael Landivar University (IARNA—Url) has generated crucial grassroots research in critical fields for the country
Host Institution 5	Universidad Mariano Gálvez Umg	School of Medicine Laboratory of Genetic Sequencing	Umg has participated in various editions as a *Converciencia* host institution Umg has recognized research capacity through its laboratories with above average (in the national context) research infrastructure and scientific human power

Source: based on interviews with staff and co-organizers from the host institutions, complemented with publicly available information. Usac, San Carlos of Guatemala University; Unam, National University Autonomous of Mexico; Url, Rafael Landivar University; Umg, Mariano Gálvez University.

TABLE 5 | Levels of analysis, *Converciencia*: policy and practice review.

Level of analysis	Descriptor	Operationalization—questions to answer	Perspective
Descriptive	It refers to the narration of the general characteristics of the policy/program/practice. Includes the most relevant features including origin, vision, participants, and resources	How was the policy/program/practice created? Who are the participants? How do actors participate? What does the policy/program/practice consist of? Which are the general characteristics?	S&T Policy Agents Media Coverage
Explanatory	It refers to the argumentation regarding the elements that impact or cause the analyzed policy/program/practice	Why was the policy/program/practice created? Why do participants take part in it? What do they do it for? What are their motivations and expectations?	S&T Policy Agents, Scientific Community, Host Institution
Normative	It refers to the set of ideas and the worldview held by the actors that influence (justify) their behavior, actions, and decisions. It is largely based on their interpretation of the ideas that shape the policy/program/practice under analysis	What are the perspectives on the general topic? What are the perspectives on the specific topic? What are the problems with the situation?	S&T Policy Agents, Scientific Community, Host Institution
Prescriptive	It refers to the "ideal" version of the policy/program/practice, a set of recommendations	What should the ideal situation look like? What should happen to improve the practice? What are the expectations? Which are the solutions to the identified problems with the practice?	S&T Policy Agents, Scientific Community, Host Institution

Source: adapted from Patton et al. (2013, p. 31).

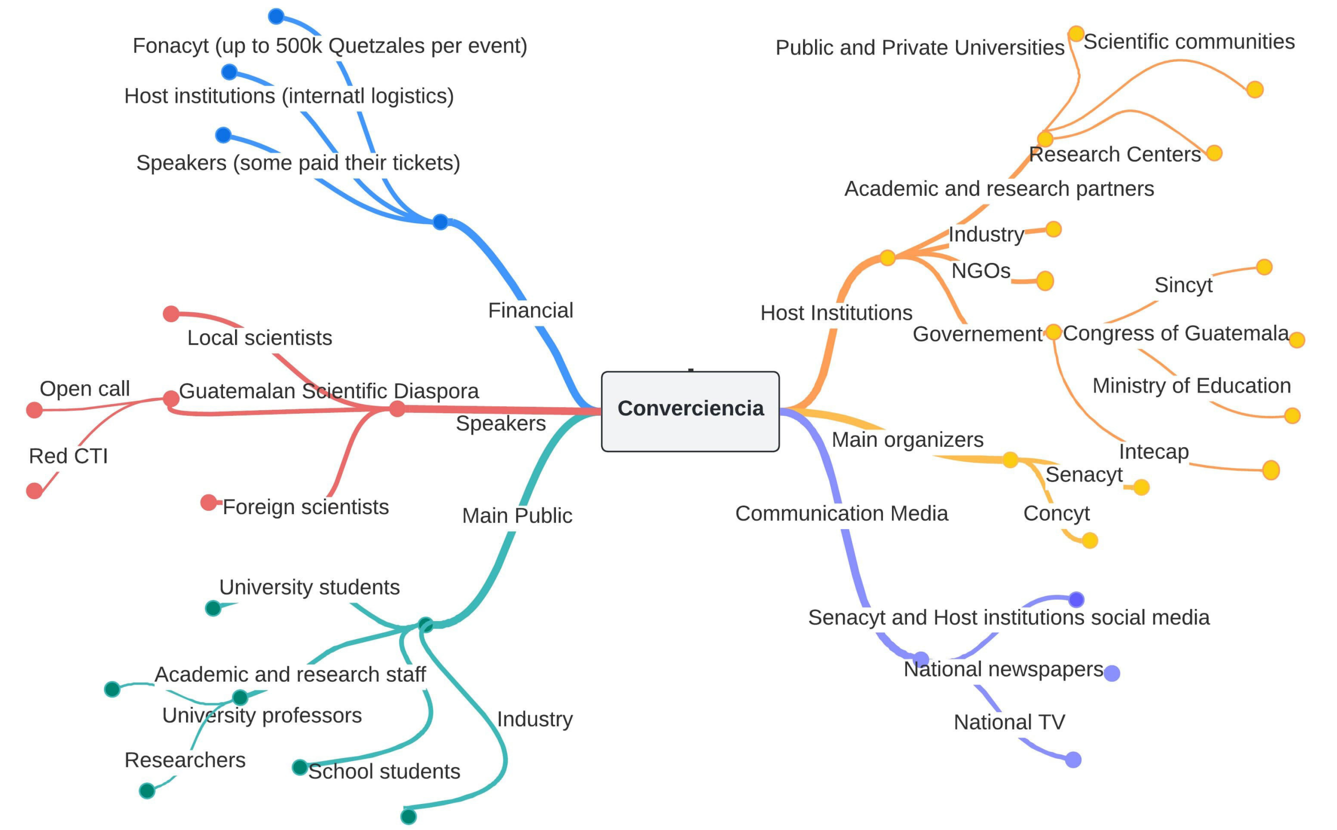

FIGURE 1 | Actors in *Converciencia*: descriptive analysis. Source: own elaboration.

development. As of February 2022, *RedCTI*[2] had 196 members. Applying a binary gender filter (male/female) in this network, 71.43% (140) are men, and 28.57% are women (56). According to their field of knowledge, this network includes 23.46% (46) in medical sciences, 31.6% (62) in natural sciences, 27.55% (54) in engineering and technology, 11.22% (22) in social sciences, and 6.8% (12) in agricultural sciences. In terms of level of education among its members, 5.1% (10) reported having completed a bachelor's degree (*licentiate*), 29% (57) master's degree, and 65.9% (129) hold doctoral degrees (Ph.D.). The reported country of residence shows that 54.6% (107) indicated their country of residence as Guatemala and that 45.4% (89) reside abroad. In this aspect, a more comprehensive concentration of GSD is found in the United States with 18.3% (36), followed by Mexico at 5.6% (11) and 4.6% in France (9). Other destinations with less presence include Argentina, Chile, Canada, Germany, England, the United Kingdom, South Korea, Taiwan, Japan, etc.

Each year, members of *RedCTI* were invited to participate in *Converciencia*. Likewise, within the framework of the event, until 2019, participation was in-person and required mobility. Members of *RedCTI* held a general assembly in which they declared the importance of the continuity of *Converciencia*. *RedCTI* considered *Converciencia* an essential space for the Guatemalan scientific community and their interaction with society, sharing the country's scientific developments.

[2]See https://RedCTI.senacyt.gob.gt/portal/index.php/investigadores/directoriocti.

The Host Institutions

Since the first edition of *Converciencia*, the role of the host institution was designed as a co-organizer sharing with Senacyt logistic, organizational, and follow-up responsibilities. The level of involvement of each host institution and the number of participants (single or recurrent) have changed over time. Universities, research centers, and a few public institutions have played a recurring role in co-organizing *Converciencia*. Among their functions, host institutions provide infrastructure (their facilities host the activities) and audience (professors, researchers, students, and staff). The activities, in the context of *Converciencia*, include academic events (round tables, panels, and discussions by experts) and visits to laboratories and different facilities. Host institutions have expressed their intention to have more influence on planning and organizing *Converciencia*. In other words, they seek to act as true co-organizers and not as passive bystanders. However, as it will be discussed later, their involvement has been limited to logistics (receiving guest speakers, attending technical aspects of the events, and providing transport to participants), with no influence on the organizational aspects of the event.

TABLE 6 | Descriptive analysis: detailed review of the annual reports, Senacyt (2005–2020).

Year	Secretary senacyt	References to *Converciencia*—Highlights from the annual reports Senacyt 2005–2020
2005	Rosa Maria Amaya	No annual report is available. Various consultations were carried out. Officers from Senacyt indicated there are no records of the 2005 Annual Report. However, *Converciencia* first edition dates to 2005 (SENACYT, 2022a,b), which is also reported in the Annual Report 2006
2006	Rosa Maria Amaya	*Converciencia* is reported in four paragraphs on page 21 (37 pages). Main highlights: Second consecutive edition of the event. Objective: Share the work of Guatemalan researchers residing abroad and promote an exchange with their peers residing in Guatemala. Main results: 40 leading conferences offered by the guest visiting researchers, estimated participation of 5,000 people in the different activities, and the celebration of the first International Assembly *RedCTI*. The term *Converciencia* is used a total of four times in the report
2007	Rosa María Amaya	*Converciencia* is reported on three pages, 30–41 (81 pages). Main highlights: 21 guests visiting researchers. Objectives: Foster interest and encourage young high school and college students toward research and science activities; involve different sectors (academic, private, and public) and the general public; raise awareness of the need and urgency to develop science and research for the development of Guatemala; increase the visibility of the work done by Guatemalan scientists visiting from abroad; and promote an exchange of visiting scientists with their peers residing in the country. No mention of outcomes of results. The term *Converciencia* is used a total of 18 times in the report
2008	Rosa María Amaya	*Converciencia* is reported on three pages 35–37 (77 pages). Main highlights: 17 Guatemalan scientists visited from abroad, and an estimated 4,000 people participated in *Converciencia* 2008. Strengthening the *RedCTI*. Objectives: Produce a critical analysis since the beginning of the event, formulation of innovations, improvements, and new academic approaches; the compilation of practical proposals to address the national crisis affecting the STI sectors; the establishment of new cooperation programs between local and foreign scientists and universities; the formulation of recommendations to the educational sector for the training of human resources in CTI. The term *Converciencia* is used a total of 13 times in the report
2009	Rosa María Amaya	*Converciencia* is reported on three pages 41–44 (106 pages). Main highlights: visit of 21 scientists who are outstanding in the international academic and scientific field. More than 3,000 participants (including researchers, University authorities, education officials, businesspeople, and others). The term *Converciencia* is used a total of 19 times in the report
2010	Rosa María Amaya	*Converciencia* is reported on three pages 52–54 (104 pages). Main highlights: Inclusion and gender perspective are incorporated in the activity with the visit of four women scientists who disseminated information about their research abroad (no other details are provided). Participation of 2,387 people, nine visiting scientists, 35 local scientists, and the development of teleconferences allowed 447 people from different locations. References are made to the signature of various international cooperation agreements with parties in Mexico, Costa Rica, and Brazil. The term *Converciencia* is used a total of 23 times in the report
2011	Rosa María Amaya	*Converciencia* is reported on three pages 46–48 (102 pages). Main highlights: Commemoration of the 7th edition. The central theme was "Environment and Population" at the suggestion of the *RedCTI* of Guatemala, with a particular focus on food and nutritional security. This year, 11 speakers from the GSD visited Guatemala, and four foreigners from Colombia, Venezuela, and Taiwan, participated. The speakers attended conferences, professional exchanges, and meetings for potential cooperation agreements. Guatemalan scientists living in the country also participated. The program received scientific and financial support for its implementation from Cyted, the International Center for Theoretical Physics (Ictp), the Taiwan government, Intecap Guatemala, and the Mariano Galvez University. The report also highlighted that for the first time, activities took place in provinces (outside Guatemala City) with the direct participation of the scientists in Chiquimula and Quetzaltenango. A cooperation agreement between Senacyt and the Center for Theoretical Physics of Colombia in research activities was signed for researchers' technological development and training in advanced areas of natural sciences. *RedCTI* celebrated its annual Assembly to accept new members and approve the work plan 2012. The term *Converciencia* is used a total of 26 times in the report
2012		*Converciencia* is reported on three pages 40–42 (72 pages). Main highlights: a workshop on Population and Territory was organized, a computer system that stores the scientific contents in the video that were treated in the event, knowledge about biotechnology was promoted to 350 high school students, and results of research related to environmental quality and water pollution. This year, 16 members of the GSD participated as speakers. They exchanged experiences and knowledge with the academic community and the public. Also, 55 scientists residing in Guatemala participated in an event organized by the Concyt Technical Commission. Four scientists from Argentina, Mexico, and Taiwan participated in the events. A set of recommendations was compiled to address national actions for the country's development. The two main topics analyzed were food and nutritional security and the country's environmental situation. In total, 5,127 people participated as an audience of *Converciencia.* Additionally, 408 connected online. A total of 62 conferences. The First Central American Workshop on Space Systems Engineering, with the participation of 25 participants, was held. The term *Converciencia* is used a total of 25 times in the report
2013	Maria Rubio Contreras	There are no references to *Converciencia* this year as the activity was suspended from 2005 to 2012. The most related event was the International Congress of Science, Technology, and Innovation; however, the specific component of including Guatemalan scientists residing abroad was eliminated. The report is 53 pages
2014	Armando PokusYaquián	The term *Converciencia* is mentioned two times on page 27 of the report; those are references to past editions of the activity. This year the activity was suspended in the way it was implemented from 2005 to 2012. The document reports the second edition of the International Congress of Science, Technology, and Innovation. Once again, no attention is paid to the participation of Guatemalan scientists residing abroad. The report is 49 pages

(Continued)

TABLE 6 | Continued

Year	Secretary senacyt	References to *Converciencia*—Highlights from the annual reports Senacyt 2005–2020
2015	Armando PokusYaquián	There are no references to *Converciencia* this year as the activity was suspended from 2005 to 2012. The document reports the second edition of the International Congress of Science, Technology, and Innovation. No reference to the participation of Guatemalan scientists residing abroad. The report is 35 pages
2016	Armando PokusYaquián/Oscar Cóbar Pinto	Senacyt did not release an Annual Report for the 2016 year individually; however, there is a multi-year 2016–2019 Report issued by Senacyt. It is indicated that this year *Converciencia* was suspended in the way it was implemented from 2005 to 2012. This multi-year report on page 152: "Senacyt, in 2017, relaunched *Converciencia* as the most prominent scientific outreach event in Guatemala, to promote the exchange between visiting Guatemalan scientists and their resident peers in the country, to share their experiences, present the results of their studies and delve into the current state of science in the region. It also seeks to foster a scientific and research culture in elementary, middle, and high school students. This academic activity stimulates the dissemination, promotion, and popularization of scientific and technological production through different mechanisms and methodologies, ensuring that the same reaches all audiences and actors linked to national socio-economic development." 2016 also marked a transition from Secretary Armando PokusYanquián to Secretary Oscar Cobar Pinto
2017	Oscar Cóbar Pinto	*Converciencia* is reported on page 22 (50 pages). Main highlights: *Converciencia* is relaunched, with 20 visiting Guatemalan scientists and 4,405 attendants. Special activities were dedicated to the participation of women in science in *Converciencia*. The term *Converciencia* is used a total of nine times in the report
2018	Oscar Cobar Pinto	*Converciencia* is reported on page 25 (53 pages). Main highlights: Commemoration of the 10th edition of *Converciencia* and its contributions to the exchange of knowledge between outstanding Guatemalan scientists residing abroad with researchers, community-academic, and the public back in Guatemala; participation of 28 Guatemalan scientists in this edition in the search for links between the academic community and scientists from the public, private, and academic sectors. The event took place in Guatemala City (capital) and various provinces. The term *Converciencia* is used a total of eight times in the report
2019	Oscar Cobar Pinto	Senacyt did not release an Annual Report for the 2016 year individually; however, there is a multi-year 2016-2019 Report issued by Senacyt in which it is indicated that *Converciencia* activities took place in 16 locations within the frame of the Sustainable Development Goals of the United Nations, these being: Energy, Water, Education, Environment, Climate Change and Sustainability, Health, Food Safety, Digital Society, and Inclusion. Activities included 78 conferences, three forums, five workshops, and 12 general activities with 31 participating scientists and 5,250 people in the Capital City and other provinces. The term *Converciencia* is mentioned 18 times in this multi-year report. The report is 259 pages
2020	Ana Chan Orantes	*Converciencia* is reported on page 9 (21 pages). Main highlights: Celebration of the 12th edition. This year, the objective was to exchange knowledge between society and Guatemalan scientists who work in scientific research, technological development, and innovation institutions inside and outside the country. Main activities responded to the Ibero-American Citizen Agenda of the Ibero-American General Secretariat -Segib- and the UN Sustainable Development Goals (SDG) (Energy, Education, Environment, Climate Change, Health, Food Security, and Digital Society). *Converciencia*, for the first time, was entirely held virtually, having the participation of 37 scientists and 2,729 attendees; 39 activities were carried out. The term *Converciencia* is mentioned a total of six times in this report

Source: own elaboration based on SENACYT (2022a,b).

Communication Agents and the Local Media

Senacyt has reached out to the media to provide coverage for *Converciencia* activities and speakers. The coverage has been focused on highlighting the academic background of the speakers, the activities in the context of *Converciencia*, and the roles and contributions of the host institutions, especially in cases with interactions between scientists, children, and young students. Frequently, the coverage has transcended the informative perspective incorporating a critical or reflective approach. News and reports have highlighted the importance of increased investment in science, technology, and innovation for Guatemala. Also, media posts written by scientists living in Guatemala have described the need to rethink *Converciencia* toward GSD engagement with local scientists beyond dissemination activities.

Reviewing the news coverage and publications addressing *Converciencia* in the leading national newspapers (see **Table 7**) makes it possible to extract headlines and trends in the program's coverage from 2005 to 2020. The review was conducted entirely online, representing a limitation as it was not a comprehensive hemerographic inquiry. Particularly in the early editions of *Converciencia*, the penetration of the internet was limited in Guatemala, and media coverage was mainly done on printed (paper) means. Notwithstanding, the reviewed media coverage included three private newspapers, *Prensa Libre, El Periódico*, and *La Hora, one* public newspaper, *Diario de America Central*, and one digital portal, *Soy502.* These news reports were the ones found in online search engines using the keyword "*Converciencia* Guatemala."

Explanatory Analysis

This level of analysis refers to the argumentation regarding elements that impact or cause the analyzed policy/program/practice.

As indicated before, Senacyt is responsible for planning and coordinating *Converciencia*. The activities related to this practice have changed, reflecting the vision and priorities set by the institution's top authority. **Figure 2** illustrates the timeline of *Converciencia's* key events. The following analysis was developed according to interviews with each National Secretariat of Science, interviews with host institutions, and public report results from the annual activities of Senacyt. In countries such as Guatemala,

TABLE 7 | Descriptive analysis: selected media coverage, *Converciencia* (2005–2020).

Year	Headline/scope and content	Links
2009	Science in Guatemala, notes from *Converciencia* 2009 by Fernando Quevedo	https://guateciencia.wordpress.com/2009/08/15/converciencia-2009-2/
2009	UN-Spider present in *Converciencia* 2009 UN-Spider was invited by the Guatemalan Council of Science and Technology to participate in *Converciencia*, which forms part of a strategy to promote the development of science, technology, and innovation within Guatemala	https://un-spider.org/sites/default/files/UN-SPIDER_Updates_July_2009.pdf
2011	*Converciencia* Guatemala 2011. *Converciencia* is the meeting of society with Guatemalan scientists who work in research inside and outside the country	https://ilifebelt.com/converciencia-2011/2011/07/
2012	*Converciencia* has motivated the interest of Guatemalan scientists—based abroad—in trying to collaborate with the country	https://www.prensalibre.com/guatemala/datos-satelites-ayudarian-pais_0_745725440-html/
2017	*Converciencia* 2017 promotes development through science and technology. The meeting of scientists is a space for the exchange of ideas and works based on science in which 26 Guatemalan scientists who work inside and outside the country will participate	https://www.prensalibre.com/tema/converciencia-2017/
2018	*Converciencia* 2018 will bring together scientists from around the world. Guatemala will bring together a quarter of a hundred scientists at *Converciencia* 2018. The event's motto will be "10 years believing in the brilliant minds of Guatemala"	https://republica.gt/2018/07/13/se-viene-converciencia-2018/
2018	Science as an escape route from underdevelopment *Converciencia* celebrates 10 years as a meeting point for national scientists residing in Guatemala and abroad and 10 years of opening a window to the development of science	https://nomada.gt/blogs/la-ciencia-como-ruta-de-escape-del-subdesarrollo/
2018	*Converciencia* as a plan to prevent brain drain. Nearly 800 Guatemalans have a doctorate, most of them obtained it abroad, and where they studied, they have stayed to live. Senacyt thought of creating a system that would offer a space for these scientists to return and share academically what has been learned outside the borders.	https://www.soy502.com/articulo/senacyt-tiene-plan-evitar-fuga-cerebros-24039
2018	Meet the brilliant minds of Guatemala. Enrique Pazos and Eduardo Rubio, physicist and astrophysicist, respectively	https://www.soy502.com/articulo/conoce-mentes-brillantes-guatemala-149
2019	Thirty-two national scientists shared experiences in *Converciencia*. Of these, 25 work abroad and 7 in Guatemala. It is estimated that 8 thousand people will participate in the scientific conclave, which will address issues on energy, education, health, food security, inclusion, environment, water, and others	https://dca.gob.gt/noticias-guatemala-diario-centro-america/32-cientificos-comparten-su-experiencia-en-converciencia/
2020	15 years of the existence of *Converciencia*. Juan Diego Chang described how the first events of *Converciencia* motivated him to study physics. Nevertheless, his opinion is that the event needs to evolve after more than 15 years. Bringing top-level Guatemalan scientists once a year is helpful, but not exclusively to give talks to the public	https://www.plazapublica.com.gt/content/quince-anos-de-converciencia
2020	Science was being carried out in Guatemala despite indifference. Local scientists described how investment in scientific research in Guatemala is scarce and believed that *Converciencia* has not produced the effect that Guatemalan scientists need	https://elperiodico.com.gt/noticias/domingo/2020/09/06/hacer-ciencia-en-guatemala-a-pesar-de-la-indiferencia/
2020	Challenges for science in Guatemala. Critical scientific advances are presented in the country, but there is still a gap in covering the entire population's needs	https://www.prensalibre.com/vida/escenario/retos-para-la-ciencia-en-guatemala/
2020	Cristina Domínguez, a Guatemalan participant in *Converciencia,* investigates how to help communities worldwide where electricity is a dream	https://www.prensalibre.com/revista-d/guatemalteca-investiga-como-ayudar-a-comunidades-del-mundo-donde-la-energia-electrica-es-un-sueno

Source: own elaboration based on media review.

where re-election is impossible, governmental officials may show a terminal logical behavior and strategic defection during transitions that affect policy sustainability. Also, new government officials dissociate from the outgoing government to fit in with the new government, leading to a lack of continuity (Escobar-Alegria et al., 2020).

Effects of Policy Shifts in *Converciencia*

Guatemala's national S & T system is a complex array of linkages between institutional representatives from entities in the public sector, the academic sector, and the private sector. Concyt governs this system (Congreso de la República de Guatemala, 1991). Concyt is integrated by nine members and is chaired by the country's vice-president. Concyt is the decision-making body providing orientation and direction to the country's scientific and technological policies and guidelines. The institution implementing such a vision is the National Secretariat of Science and Technology (Senacyt). In other words, the top authority who can influence the STI policy shifts in Guatemala is the Vice President. In this sense, at this level of analysis, it is

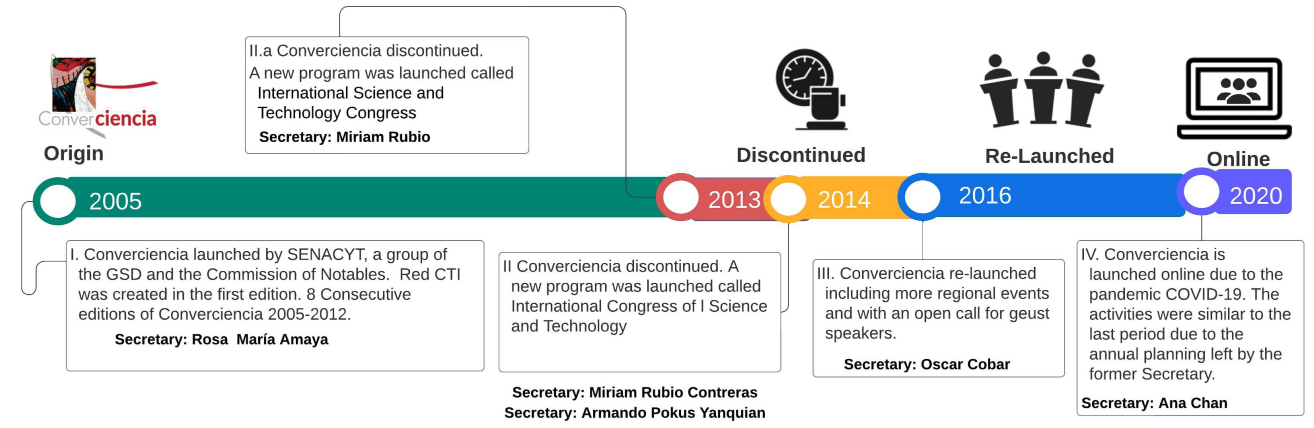

FIGURE 2 | Timeline: *Converciencia* (2005–2020). Source: own elaboration.

relevant to have in perspective who has occupied such positions during the study period.

Converciencia 2005–2012 (Vice President Eduardo Stein From 2004 to 2008 and Vice President Rafael Espada From 2008 to 2012)

Secretary Rosa Maria Amaya was among the co-founders of *Converciencia* in 2005. Her background career is in economics and project management. Her professional trajectory has progressed primarily in public administration and academia. Her linkages with scholars and researchers were strong. She purposefully built ties with the Presidential Commissioner of Science and Technology, most prominent Guatemalan researchers, and GSD members, which allowed her to launch the first *Converciencia*. The main objectives of this initiative were (i) strengthening science and technology in the country, (ii) exchanging experiences with the GSD, and (iii) seeking solutions to latent problems in Guatemalan society.

Additionally, to be the first program of its kind searching for collaboration with GSD and local scientists, the results from the first *Converciencia* went beyond founding *RedCTI*. Not all established local researchers participated in the conception of *Converciencia*, only awardees of the National Science Medal. This created continuous friction over time. Various researchers working and residing in Guatemala with established careers describe *Converciencia* as an elitist event where they were not invited, and their work in the country was not valued.

Converciencia 2013–2016 (Vice President Roxana Baldetti From 2013 to 2015 and Vice Presidents Alejandro Maldonado and Alfonso Fuentes, 2016)

In the following period, under the mandate of Secretary Miriam Rubio Contreras (January 2013–September 2014), with a background in industrial engineering and academic and industry trajectory, *Converciencia* was suspended (Cobar, 2015). Rubio Contreras indicated she "could not identify the social impact of *Converciencia* after reviewing the investment budgets in the previous years." Therefore, Rubio Contreras decided to launch the International Science and Technology Congress, with similar activities as *Converciencia* but opening other spaces for the *RedCTI* interaction with local researchers. According to her interview, a program of interchange with the former International Coordinator of *RedCTI* opened exchange programs with several students. Local researchers identified these events as having similarities to *Converciencia*. However, scientists from the Guatemala diaspora were not purposefully invited.

The National Secretary of Science, Armando Pokus Yanquian, with a background in civil engineering and project management, considered that *Converciencia* was not valuable. He did not identify a positive impact of bringing the scientists' diaspora to Guatemala for one week a year to Guatemala City to share experiences, especially when 80% of the participants were the same each year. Pokus Yanquian launched the National Week of Science and Technology in different regional locations of the country. His goal was to engage the youth to pursue science careers in other departments of Guatemala. Local researchers liked the regional approach, but the program was focused on dissemination to young generations and there were no other potential collaborations. The GSD was not invited to this event, and *RedCTI* was inactive. This period shows a steep decrease in the participation of scientists. The general political situation in Guatemala was unstable, reflected in the consecutive transition between three vice presidents in this period. Cobar (2015) reported:

> The dissemination of scientific advances in the country and the world are discussed at the Annual Conference on Science, Technology, and Innovation. This event has been held since 2013 in Guatemala City and several departments inside the country. The Congress is attended by national and international scientists who are experts in various branches of knowledge. The investigations carried out in the system are disclosed, forum panels are held, and seminars on current issues of national interest are conducted, among others. This event replaces *Converciencia* and the National Science and Technology Week events held previously (Cobar, 2015, p. 191, 192).

Converciencia 2017–2019 (Vice President Jafeth Cabrera)

Oscar Cobar Pinto was the Secretary who relaunched *Converciencia* after the political period between 2013 and 2016. Cobar's background is in organic chemistry; he is part of the GSD that came back to the country. He was awarded the National Medal of Science in 2002; he was a member of the Notable Commission of Guatemala and a *Converciencia* co-founder. His strong relationships with the Guatemala System of Science and Technology (Sincyt) led him to envision linking the GSD with the scientific community in the country. He was interested in bridging the academic sectors from Guatemala with the GSD for potential collaborations. In addition, his priority was to promote science for the Guatemalan new generations. One of the first modifications of *Converciencia* during that period was to locate some activities in different regions of the country and different host institutions using the universities as part of the scenarios to develop collaborations. *Converciencia* had public open calls to apply as a speaker, making it easier for other scientists interested in the event. Host institutions selected their preferred speaker and activity from a list provided by Senacyt. The GSD participating in *Converciencia* felt a significant affinity to the vision of the head (related to his scientific background). Most of the scientists from the diaspora felt that their voices were heard. Nevertheless, some local scientists considered they were not the protagonists of these events, causing conflicts in their perception. Host institutions also felt left out of the planning, limiting the outcomes.

Converciencia 2020 (Vice President Cesar Guillermo Castillo)

At the time of this research, Ana Judith Chan was the incumbent National Secretary of Science, who has a master's degree in International Business Law. She is a former President of the Guatemalan Mexican Chamber of Commerce and Industry (Camex). She considered *Converciencia* as "one of 20 activities implemented by Senacyt each year." Her vision for *Converciencia* was to restructure the activity to be more connected to the Guatemalan population, the country, and the industry's needs. She considered the past events of *Converciencia* as activity occasions disconnected from the harsh realities of Guatemala. Her perception of *Converciencia* was of a time and resource-consuming event with limited results and impact. In 2020, *Converciencia* was developed without significant changes in organization and scope; however, due to the COVID-19 pandemic, the event was entirely implemented through remote/digital online formats with no in-presence activities. Researchers appreciated that the event was online, and there were no significant expenses involved (mobility, air travel, logistics). The GSD participating in the event had a larger audience, but interactions with peers and networking opportunities were constrained.

Normative Analysis

This level of analysis refers to the set of ideas and the worldview held by the actors that influence (justify) their behavior, actions, and decisions. It is based primarily on their interpretation of the ideas that shape the policy/program/practice under analysis.

Converciencia Limitations

The analysis of Senacyt's annual reports released between 2005 and 2020, contrasted with the assessments derived from the focus groups, allows for the emergence of *Converciencia's* limitations found in its design, coordination, and evaluation processes. These three aspects show that although Senacyt gave greater relevance to the participation of the scientific diaspora during the days of the event, they were neither included in the previous stages (planning) nor in the posterior stages (monitoring, evaluation). The priorities of *Converciencia* topics were driven by the government's vision and did not engage the GSD with the rest of the scientific system. **Figure 3** illustrates *Converciencia* limitations.

Design Limitations

Although *Converciencia* was conceived as a program contemplated in the National Plan for Science, Technology, and Innovation (2005–2014), over time, the policy perspective shifted and reduced it to a yearly event. The annual reports repeated knowledge exchange as a critical characteristic of *Converciencia*, but according to Participant (2022b), the dissemination activities were from the GSD to the participants with a unidirectional approach. Also, *Converciencia* has a centralized approach because it has been held mainly in the capital city[3]. Despite the event being sustained over time, the general objective has not been standardized and has changed confusingly and diffusely in each new administration.

Coordination Limitations

There is no homogeneous process and clear criteria regarding who and how the topics of discussion for each event are defined. The decision-making process is restricted to Senacyt in various editions of *Converciencia*. The institutions have not involved the scientific community represented by *RedCTI* in the organization, elaboration of a plan, and activities, even though this network of Guatemalan scientists was created precisely as the co-founding party *Converciencia* back in 2005. There is no specific information on whether the decisions[4] for the scope and thematic to be included respond to the agenda of the government, the scientific community[5] (or the network), the international community, civil society, or the national scientific and technological system. This reveals the reduced or even null participation of other sectors in the definition of the agenda and its priorities and the general organization of the event,

[3]There were some efforts to extend the event to the countryside, as in the 2011, 2018, 2019, and 2020 editions.

[4]Except for the 2011 edition where that year's report mentions that the central theme "Environment and Population" was chosen based on the Network's suggestion.

[5]Although the reports make direct reference to the fact that issues addressed are of national interest, and in the case of the 2019 and 2020 editions, arise from the Citizens' Agenda in Ibero-America and the Sustainable Development Goals, they do not clarify whether the choices were adopted in coordination with the diaspora, social organizations, or the offices of the Ibero-American General Secretariat and the UN in Guatemala.

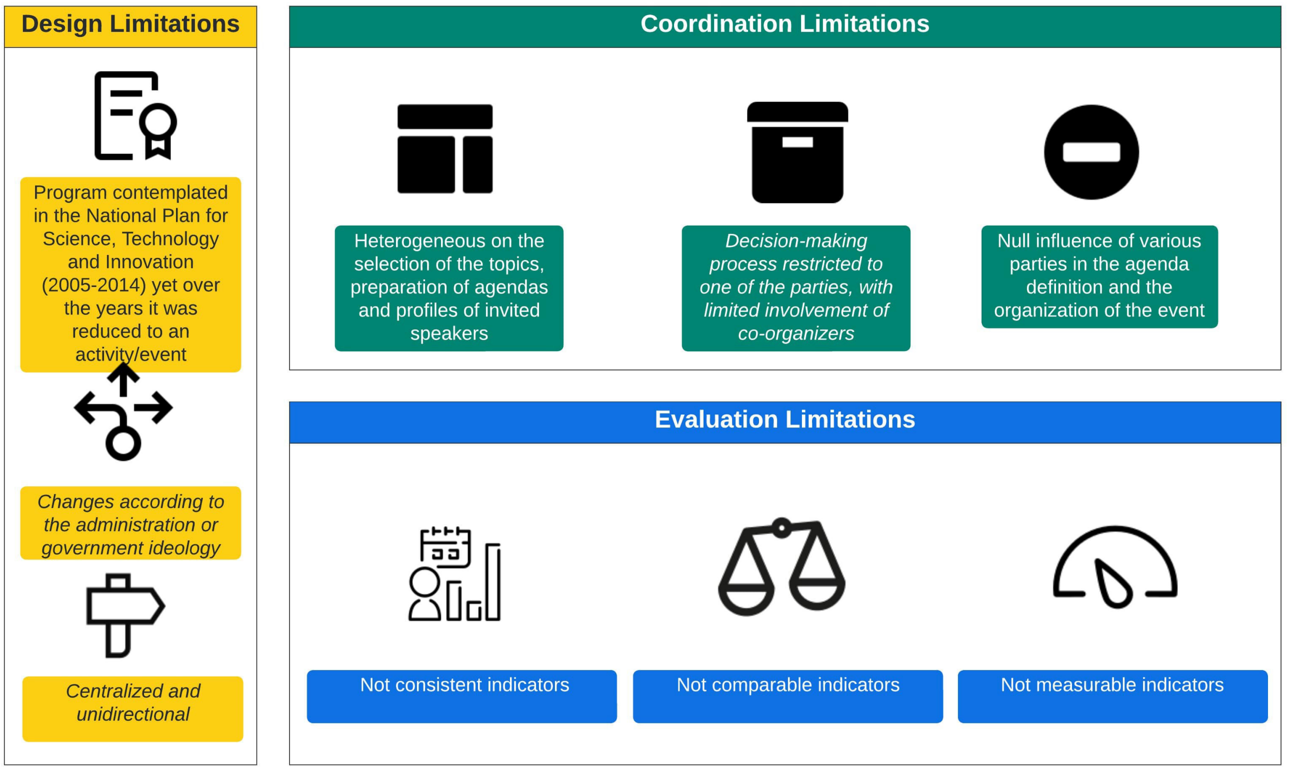

FIGURE 3 | Limitations of *Converciencia* as a science and technology practice. Source: own elaboration.

which affects the effectiveness, willingness, and viability of the dissemination and exchange of knowledge with the GSD.

Evaluation Limits

The annual reports from the last 15 years have not included any information about financial resources and the budget allocated to *Converciencia*. Moreover, the results and impact indicators are not comparable between years. For example, only in a few editions, the number of academic collaborations between researchers was measured. The reports focused on the number of speakers and participants. However, no specific information on the type of knowledge exchange, agreements developed, joint publications, and different collaboration categories has been reported.

Converciencia SWOT Analysis

To better understand the perception of the scientists who have participated in past editions of *Converciencia*, a SWOT analysis was conducted with data derived from the focus group discussions and interviews with 25 scientists and 3 stakeholders representing civil society, industry, and academics (see **Figure 4**).

Strengths

Converciencia has enabled interaction between scientists from the diaspora and those working in the national territory with students, educators, and broader sectors of Guatemalan society. The event has shown undergraduate students the opportunity to become researchers and pursue graduate studies, primarily to obtain a doctoral degree. In recent years, scientists who have participated in *Converciencia* have identified the program's transformation involving more women, young scientists, and local scientists as speakers. Also, in the last years, more locations have been included, decentralized to the capital city, and even involved a digital format in 2020 because of the COVID-19 pandemic. Another advantage is that scientists outside the country can learn the current research, technology, and innovation system challenges from scientists living in Guatemala. In addition, scientists from the GSD identify that one of the main strengths of *Converciencia* is that it has been the only mechanism in the country that has allowed them to meet and interact with more Guatemalan scientists. The networking between scientists participating in the event has allowed for friendships that have become collaborations for grants and publications over time. Due to the country's conditions, scientists conducting research work in Guatemala engage in collaborative work with scientists residing in other countries who participate in *Converciencia* with their own institutional or personal funds (no receiving financial support from a Guatemalan institution/organization). Researchers appreciate the GSD attitude toward learning and collaboration. Media coverage of the importance of science during the event has been one of the strengths highlighted by local researchers. Moreover, *Converciencia* is well-established and

Strengths

Guatemalan Scientific Diaspora:

-It has been the only mechanism in the country that has allowed the diaspora to meet and interact with more Guatemalan scientists.

-The networking between scientists participating in the event has allowed friendships that over time have become in collaborations for grants and publications.

-In recent years more women, young scientists, and local scientists were involved.

-Running for many years facilitating marketing and promotion strategies.

Local Scientists residing in Guatemala:

-The interaction between scientists, students, and teachers has promote the importance of research careers and doctorate programs.

-Scientists residing outside the country can learn from the scientist living in Guatemala the current research, technology, and innovation system challenges in the country.

-In 2020 it had a digital format alowing less expenses.

-The high media coverage of the importance of science during the event

Weaknesses

Guatemalan Scientific Diaspora:

-The lack of engagement of local scientists, and other stakeholders.

-No match between scientists working in the same area to generate collaboration.

-The number of events assigned to each scientist has been extensive in dissemination.

-No defining the target public; it has not been clear to the audience or the scientist participating.

-Bad logistics in the event planning, timing and booking.

- The scientific diaspora have not been considered for co-designing the program.

Local Scientists residing in Guatemala:

-Unidirectional without room for collaborations.

-Lack of regional participation and inclusion of indigenous scientists or indigenous participants.

-One-time a year event; for most participants, it does not have continuity in collaborations with the other researchers.

-None of the events had translations to Mayan languages.

-No evidence of the benefits achieved with the funds expended in the program.

-The local scientists have not been considered for co-designing the program..

-Repetitive profiles of scientists in the events.

Opportunities

Guatemalan Scientific Diaspora:

-Vinculation to create real collaborations between scientists residing abroad and within the country.

-Links between scientists and NGOs, civil society, and industry.

-Co-design Converciencia with established goals, targets and collaborations

Local Scientists residing in Guatemala:

-New Guatemalan generation of scientists with energy to transform the country.

-Designing Converciencia in collaboration with universities, research centers, Red CTI and local scientists with a more collaborative approach

-Secure funding

Threats

Guatemalan Scientific Diaspora:

-Changes in funds and formats occur when the government changes.

-Unwillingness of decision-makers to allocate a budget to science, technology, and innovation.

Local Scientists residing in Guatemala:

-Focus of the policy has been changing with every new Senacyt head.

-Politic propaganda

-Lack of science investment.

-Wrong signal that science can only be done outside of Guatemala.

FIGURE 4 | *Converciencia* strengths, weaknesses, opportunities, and threats (SWOT) analysis. Source: Own elaboration.

well-known, and has been running for many years, facilitating marketing and promotion strategies. The joint doctoral program between Unam and Usac organized by one of the researchers visiting the event has been one of the outcomes of *Converciencia* that have generated measurable results, i.e., various Guatemalans who graduated from doctoral programs currently occupy leading positions in academia, mobility, and research exchange between Unam and Usac, and other collaboration agreements with Cambridge University and Ictp organized by the other co-founders of *Converciencia*.

Weaknesses

Lack of engagement of local scientists with the event has been identified in all the interviews. There have not been enough incentives for local scientists to participate. There has not been a match among scientists working in the same area to generate spaces for collaboration. The number of events assigned to each scientist has been extensive, limiting only to disseminating research results and not allowing communication between different sectors to evaluate collaboration opportunities. *Converciencia* is a one-time a year event; for most participants, it does not have continuity in collaborations with other researchers. Many activities have been organized without defining the target public; it has not been clear to the audience or the scientists participating. Stakeholders from the industry had identified the lack of participation of industry and other sectors in these events. Also, the profiles of scientists have been repetitive every year. Participants have also specified bad logistics in event planning, timing, and booking, including lack of regional participation and inclusion of indigenous scientists or indigenous participants. None of the events were available in indigenous languages. Most of the researchers residing in Guatemala consider that the program has more weaknesses than strengths. They have described the program as unidirectional without room for collaboration. Additionally, there is no evidence of the benefits achieved with the funds expended in the program. Guatemalan scientists, including the members of the *RedCTI*, have not been considered for co-designing the program. This group should be fundamental to *Converciencia* planning due to their seminal contribution to the origin of the program.

Opportunities

One of the main opportunities identified is that the platform could allow for follow-up and concrete collaborations between scientists residing abroad and in the country. It can also promote connections among scientists, NGOs, civil society, and industries. Also, a new cohort of scientists has been identified as an opportunity. This is because of the renewed energy and innovative ideas that they can potentially bring. Designing *Converciencia* in collaboration with universities, research centers, *RedCTI*, and local scientists has been identified as an opportunity to create longer and established relationships between the participating scientists. According to the local researchers, The *Converciencia* funds' allocation in the Senacyt annual operation plan should continue but under a collaborative approach focusing on Guatemalan researchers' needs. *Converciencia* has an assigned annual budget that can continue over time and is an advantage to consider with a better restructuring and with a more collaborative approach to listening to the Guatemalan researcher's needs. Likewise, there is an opportunity to invite scientists who carry out scientific dissemination to participate in the event.

Threats

The main threats involve changes in policy direction, budget allocation, and structure of the event which occur when the government administration changes. The focus of *Converciencia* has been changing with every transition in the top direction of Senacyt. Moreover, there is not enough participation of established local scientists who consider *Converciencia* an elitist event. They perceive that the event only highlights the work of Guatemalan scientists residing abroad, along with local results. Another threat identified by researchers living in Guatemala is the potential message that science can only be done outside Guatemala. According to researchers, politicians on duty have been another threat since they guide the event for their propaganda interests. The most significant danger mentioned by all scientists is the unwillingness of decision-makers to allocate a budget to science, technology, and innovation.

The perspective of the host institutions is critical for explaining different challenges and opportunities experienced in their roles as co-organizers of *Converciencia*. **Figure 5** summarizes the main findings derived from the data collected from the institutional actors.

Prescriptive Analysis

This level of analysis refers to the "ideal" version of the policy/program/practice, for which actors and stakeholders present a set of recommendations to improve.

Converciencia As a Policy and Practice

The evidence of successful results from *Converciencia* offers opportunities to assess its relevance as a policy/practice. Participant (2022b) provided a few examples of mobility and international collaborations rooted in the first edition of *Converciencia*; "various outcomes can be traced back to *Converciencia* including the creation of a "joint doctoral program" co-organized and implemented between the University of San Carlos of Guatemala and the Autonomous University of Mexico." Another example is the research visits of Guatemalan students to the International Center for Theoretical Physics (Ictp) in Italy. In addition, the transfer of environmental virology with the University of Barcelona was promoted. These three initiatives were promoted by three scientists from the GSD who co-founded *Converciencia*, Concepción Toriello, Fernando Quevedo, and Oscar Cobar Pinto. These examples shared as a common feature the need to follow up and engage in sustained collaborations as opposed to episodic, isolated activities.

According to Participant (2022a), a vision focused on entrepreneurship has been favored instead of research and development in recent years, even in the health crisis derived from the COVID-19 pandemic. Participant (2022a,b) considered that *Converciencia* should focus on inter-institutional exchanges and transfer knowledge by co-creating postgraduate programs

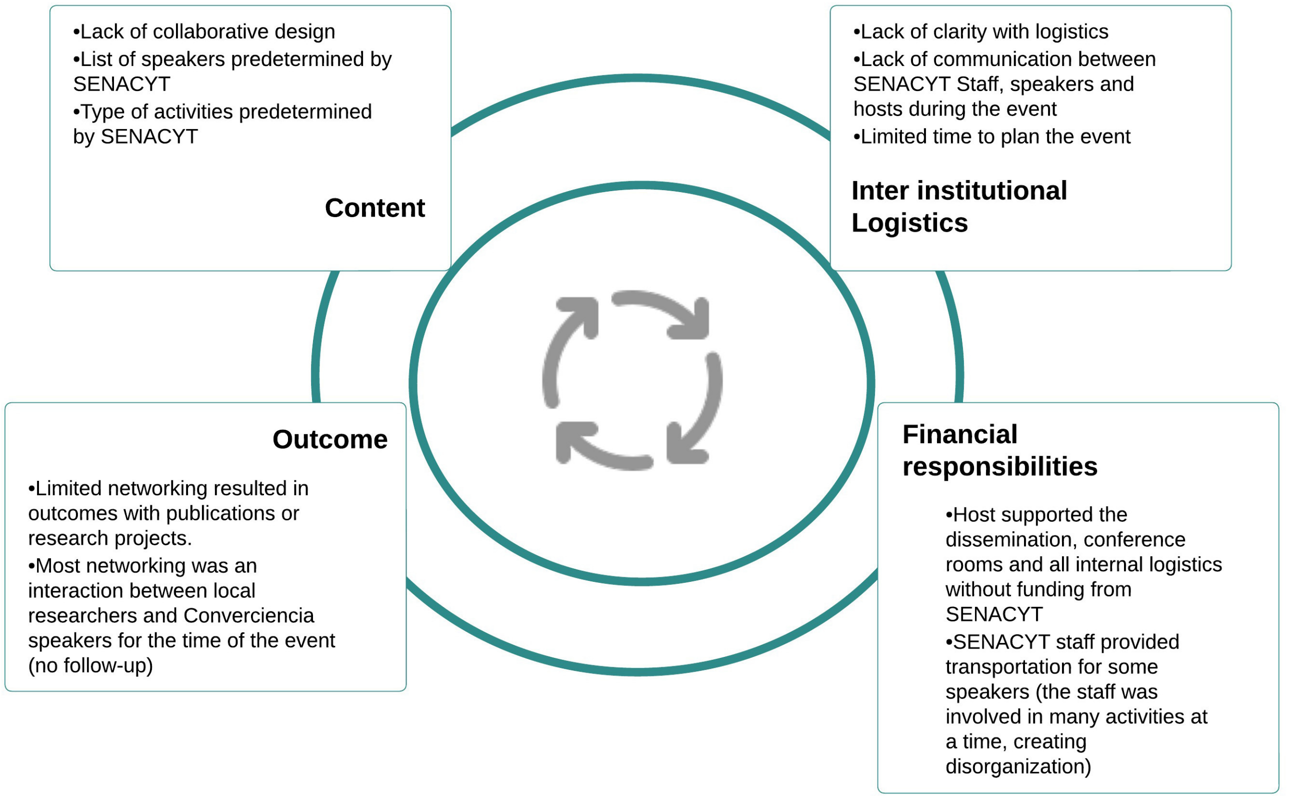

FIGURE 5 | Co-organizing *Converciencia*: perspective from the host institutions. Source: own elaboration.

with GSD institutions and local institutions. Another participant provided an example of results from *Converciencia*, a joint publication derived from the 2019 edition in which a member of the GSD working in Chile collaborated with scholars in the host institution and presented the research results in international conferences and journals.

Converciencia has responded, according to some comments from the Participant (2022b), to an elitist vision resulting in exclusionary practices. These cognitive characteristics in public management generate biases that privilege the "well-known" [speaker's profiles] and devalue diversity. *Converciencia*'s repeated patterns of lack of institutionalized policies are due to the volatility and distrust from Senacyt and/or Concyt top authorities[6]. These patterns relegated the local scientists and the GSD in the decision-making, management, and engagement.

Converciencia's strengths and weaknesses over the years can lead us to restructure policies according to the demands of the scientific community and social and economic needs. Nevertheless, *Converciencia* has a strong policy to engage the GSD, and local scientists need a co-governance model with a stable budget. Moreover, Senacyt and Concyt need to plan beyond administration and focus on the scientific content from a collaborative perspective with the key actors. These collaborations will create an environment for brain re-circulation and diaspora networking.

Converciencia As a Potential Successful GSD Engagement Policy

All the actors involved in different periods and stages have highlighted several weaknesses of this policy. Nevertheless, it does not mean that the scientific community is not interested in the continuation of the program. The Guatemalan scientific diaspora and local Guatemalan researchers agree that *Converciencia* must continue with restructuring and co-design and with the participation of the Guatemalan scientific community and other key stakeholders. There is a growing interest in the application of "design thinking" to policy-making (McGann et al., 2018). In the following sections, we describe five critical steps of co-design thinking that could be adapted to the policy and potential recommendations for this process. Usually, government science policy organizations in developing countries do not coordinate their activities between possible users of their technological innovations that are absent or unsatisfactory (Crane, 1977). The development policy is often considered policy creation found in advanced economies and developing countries' interventions and should be limited to promotion (Bell and Hindmoor, 2009). Accordingly, there is a democratic deficit of

[6]Except for the Cobar administration, the Participant (2022a) stated that it has been difficult to work with the Secretaries of Senacyt, because they have had limited understanding of the complexities faced by scientists, and that they have focused merely on administrative issues with no context of scientific production.

citizen participation in the definition and formulation of issues concerning science, technology, and innovation, contrary to the strong involvement of entrepreneurs and corporations (Viales-Hurtado et al., 2021).

Empathizing With the GSD and Scientific Community Back in Guatemala

According to recent research in science policy practices for Guatemala, some key and charismatic individuals can act as door openers to link community organizations and science policy networks (Aguilar-Støen, 2018). Engagement by focus group discussions or online surveys could help Senacyt to understand the view of the parties involved by incorporating different perspectives. It can help understand the perspective of local scientists and their need to collaborate with the SD including scientific dissemination, research exchange programs, co-writing research proposals for international and national funding, and opportunities for equipment donation. It can help understand the perspective of the SD and their readiness to contribute to strengthening the S&T context of their country of origin. The GSD can collaborate with local researchers with respect to sharing and learning scientific knowledge, available funds for supporting research, potential collaboration agreements with their affiliated institution and Guatemalan institutions for joint research, channel donations, grants, and scholars' opportunities among others. It can help understand the perspective of universities and their need for scientific knowledge, scholarship for students, researchers, and professors, among needs for co-designing doctorate and masters' programs with a mobility format. There is evidence that the role of universities in Central America as research and innovation hubs could support design and implement flexible, transparent, and robust strategies toward the achievement of sustainability in the region. The thematic, technical, evaluative, and procedural areas provide a comprehensive framework to build capacities adapted to the functions and responsibilities of the actors (Miquelajauregui et al., 2021). It can also help understand the perspective of research centers and their need for equipment, funds, research interchanges, and co-teaching. This can also help understand the perspective of the industry and their need for the technology solution and research and development to innovate their products or services. It can help understand the perspective of civil society organizations and their needs to solve community and country health, economic, nutrition, energy, and other critical problems. Finally, it can help understand the perspective of the government and their need to support their work with science and technology, i.e., the Ministry of Health and their management of the pandemic and the Ministry of Education and their STEM programs.

Recent research on multi-level storylines applied to socioeconomic and hydrological processes showed results of engagement with the indigenous Mayan community from Atitlán (Bou Nassar et al., 2021) (i) helped develop an understanding of scientific mechanisms, (ii) initiated a dialogue between indigenous people and non-indigenous stakeholders, and (iii) extracted potential solutions targeting the system's leverage points. Therefore, this methodology could be helpful for *Converciencia* policy planning involving marginalized stakeholders, mainly Mayan communities. Strengthening the roots, increasing collaboration, and capacity-building are undoubtedly central to the bottom-up theory for science, technology, and innovation activities (Lema et al., 2021).

Defining Strategic Collaborations

There are plenty of problems in Guatemala including: quality of education, poverty, food insecurity, weak governance, endemic corruption, violence, citizen insecurity, lack of respect for human rights, and inequitable access to economic opportunities (U.S. Department of State, 2021). The National Plan of Development K'atun prioritizes the progress of a rural and urban Guatemala, wellbeing, present and future use of natural resources, and the role of the state as guarantor of human rights and driver of development. The National Policy of Science and Technology 2015–2022 prioritizes forming high-level human capital, research based on social and productive demands, innovation and technology transfer, and scientific and technological popularization. Therefore, linking the ideas collected from the empathize stage with the lines of priority for the country defines the problem to be solved in *Converciencia* as a policy and not only as an event. Nevertheless, none of these recommendations could work without the commitment of key actors, including the *RedCTI* created during the first year of *Converciencia*. Also, Senacyt should be committed to courses of action and funding priorities concerning *Converciencia* as an engagement policy with the GSD.

Ideating With the Key Actors

Ideating is the process of thinking outside the box by brainstorming with key actors to attack the problems defined. This stage aims to design a solution for restructuring *Converciencia policy*. Citizens, local researchers, and the GSD may suggest relevant local knowledge and contribute novel ideas since they are not burdened by professional expertise (Reich, 1996; Fung, 2006). Ideating is also an interactive stage between prototyping and testing.

Prototyping the Solution

The policy cycle model has a sequential development rational approach. The model first defines the problem, then formulates the policy and implements it, and finally evaluates it (Knill and Tosun, 2020). Usually, in this structure, the decision-making on the final policy is focused on the policy sphere and not on the key actors. Prototyping has a more humanistic approach to the policy than a systemic, deterministic approach (Camburn et al., 2017). Prototyping is learning about an idea's strengths and weaknesses and identifying new directions (Brown, 2008). This stage is not focused on the outcome but on the learning that helps policymakers, researchers, and key actors make the policy's idea more real before investing in it (Stanford Law School, 2018). The role inspires a taxonomy for policy prototypes, look and feel, and implementation. In this case, the Senacyt team, *RedCTI*, researchers, and other actors interested in the codesigned policy could analyze the following questions: (i) How does *Converciencia* policy impact the GSD? (ii) How does it feel

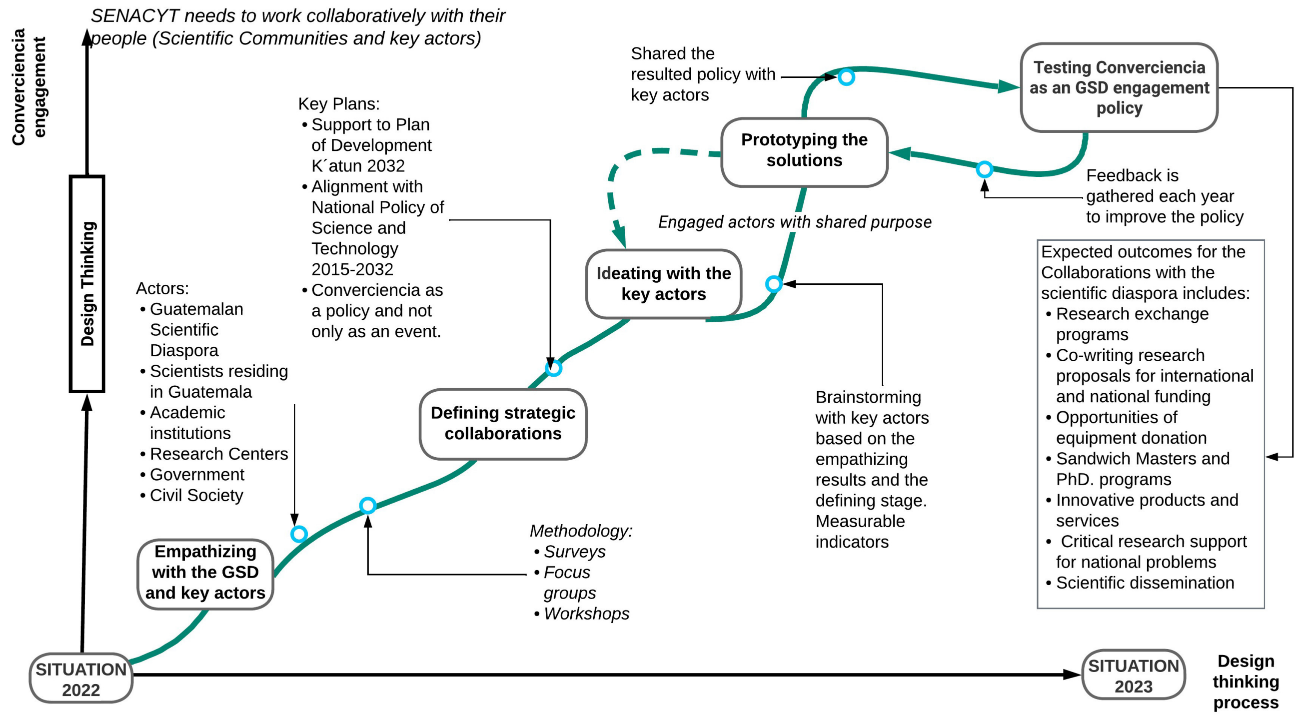

FIGURE 6 | *Converciencia* as a policy to engage the Guatemala scientific diaspora (GSD). Source: own elaboration.

to the GSD, local researchers, and the research, technology, and innovation system representatives? (iii) How does it work for the GSD and local researchers?

Testing Converciencia as an Engagement Policy

The *Converciencia* policy is implemented during the first year, and feedback from key actors is gathered. The iterative effect supports an improvement of the policy. For this stage, it is vital to have key indicators and metrics that measure the main results' progress over time. Until recently, the indicators presented are (i) the number of dissemination activities, (ii) the number of participants, and (iii) the number of speakers. Nevertheless, some of the expected indicators from scientists and host institutions for an efficient *Converciencia* policy are: (i) the number of research visits from local Guatemalan researchers, professors, and students to foreign GSD affiliated institutions, (ii) the number of exchange research visits from the GSD to Guatemala, (iii) the number of co-written research proposals between the GSD and local researchers, (iv) the number of scientific publications that resulted from collaborations between *Converciencia* participants, (v) the number of scholarships for local students, professor, or researchers that resulted from interaction with the GSD, (vi) the number of equipment donated through the GSD management, (vii) the number of joint Master or Ph.D. programs co-created with the GSD and local scientists, (viii) the number of young Guatemalan inspired to pursue a scientific career due *Converciencia*, (ix) the number of research or development projects funded and approved because of the collaboration of *Converciencia* participants, (x) the amount of investment from the Guatemalan industry for research projects with *Converciencia* participants, and (xi) the number of new spin-offs or start-ups generated through research results of *Converciencia* collaborations, among others. **Figure 6** illustrates using design thinking for the prescriptive analysis of the ideal *Converciencia*.

AUTHOR CONTRIBUTIONS

KB: conceptualization (lead), data curation (lead), project administration (lead), methodology (lead), resources (lead), validation (lead), and writing the original draft (lead). SA: conceptualization (equal), data curation (equal), supervision (equal), project administration (equal), writing the original draft (equal), and visualization (lead). LGVP: investigation (supporting), visualization (supporting), conceptualization (substantial), and writing (original draft, supporting). All the authors contributed to the article and approved the submitted version.

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BRIEF RESEARCH REPORT
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Engaging Scientific Diasporas in STEAM Education: The Case of Science Clubs Colombia

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Currently, there is limited insight on the role that scientific diasporas can play in STEAM education in Latin America. Here, we present the Science Clubs Colombia (Clubes de Ciencia Colombia-SCC) program, a pioneering STEAM capacity-building initiative led by volunteer scientists to engage youth and children from underserved communities in science. The program brings together researchers based in Colombia and abroad to lead intensive project-based learning workshops for young students in urban and rural areas. These projects focus on channeling the students' technical and cognitive scientific aptitudes to tackle challenges of both local and global relevance. The program provides high-quality STEAM education adapted to communities' needs and articulates long-lasting international collaborations using the mobility of the Colombian diaspora. The program's success is tangible via its sustained growth and adaptability. Since its first version in 2015, 722 volunteer scientists living abroad or in Colombia have collaborated to create 364 clubs with the participation of 9,295 students. We describe elements of the SCC program that lead to a scalable and reproducible outcome to engage science diasporas in STEAM education. Additionally, we discuss the involvement of multiple stakeholders and the generation of international networks as potential science diplomacy outcomes. The SCC program strengthens the involvement of Latin American youth in science, demonstrates the potential of engaging scientific diasporas in science education, and enriches connections between the Global South and the Global North.

Keywords: educational policy, Colombian scientists, scientific diasporas, STEAM education, scientific vocations, K-12 education

INTRODUCTION

Preparing youth for current and foreseeable global challenges should be a top priority, and an endeavor reaching all geographical and social contexts. In particular, curricula in STEAM (Science, Technology, Engineering, Arts and Mathematics) education are at the core of this task. Through high-quality STEAM education, students acquire crucial skills such as critical thinking, perseverance, creativity, innovation, and collaboration. These essential competencies increase access to job stability, higher income, and productivity, which are vital to a nation's growth (Vuorikari et al., 2016) and to address pressing challenges worldwide. Furthermore, a highly educated workforce is paramount to drive economic development and build a knowledge-based economy (NSF, 2014; UNESCO, 2017). Thus, it is crucial for nations to implement education policies that develop critical skills for problem-solving and build research capacity for their countries (Greenbaum and Hajjar, 2017).

Science Clubs Colombia (Clubes de Ciencia Colombia, 2022[1], henceforth SCC) is a grassroots educational program created and developed by volunteer scientists to address this challenge. Inspired by the pioneering work by *Science Clubs Mexico*, the program was born in 2015 led by Colombian scientists as a hands-on learning experiential initiative for youth. Nowadays, the program's mission is to mobilize the scientific diaspora for STEAM education in Latin America, contributing to high-quality STEAM education in underserved communities (Franco et al., 2019). The model has grown to include Colombian and non-Colombian volunteers located worldwide as part of the Latin American initiative *Science Clubs International*[2].

In Colombia, the program is sustained by a network of volunteers who work with support from both private and government entities (**Figure 1**). Currently, SCC is affiliated with ScienteLab, a non-profit organization that seeks to strengthen science and technology appropriation processes in different contexts, focusing on youth and children in Latin America. Also, SCC has established important relationships with governmental institutions that provide financial support, yet not on a permanent basis. As a program, the goals of SCC are (1) to increase access to high-quality STEAM education for Colombian children and youth by engaging the scientific community in the country and abroad, and (2) to facilitate connections between the diaspora and local scientists and communities.

These goals are addressed by the program through the execution of "Science Clubs", science workshops delivered to youth and children across the Colombian territory. As described in detail in Section Science Clubs—The SCC Approach, these science clubs are led by teams of scientists based in Colombia and abroad. To make these Science Clubs possible, the volunteer team, consisting of Colombian scientists based both in the country and abroad, is essential. They donate their time to articulate several tasks, including fundraising, recruitment and selection of instructors and students, media and communications management, finance administration, material purchase, logistics, and workshop design support. The volunteers work alongside logistic teams to ensure the science clubs take place as planned. This task force constitutes a synergistic cooperation, connecting and engaging members of the Colombian scientific diaspora. Importantly, as part of the more extensive network of *Science Clubs International*, these alliances transcend a single country and have become increasingly more robust between the different countries that take part in the project in and beyond Latin America.

In this report, we first outline the motivation and context in which the SCC model has been developed. We then describe the foundational elements of the program and the primary outcomes in the past seven years. Furthermore, we expand on the potential implications of engaging scientific diasporas as a potential science diplomacy strategy to advance STEAM education in Latin America.

The Potential of Science Diasporas Within STEAM Education

Higher education is a strong driver of emigration in developing countries, especially among STEAM professionals (Dodani and LaPorte, 2005). Since Latin America overall invests less in STEAM, the access to funding and career options is lower for researchers in the region (Valenzuela-Toro and Viglino, 2021). The migration of scientists and STEAM higher education students to high-income nations is thus a significant challenge affecting human capital building in Latin America. This phenomenon, generally known as brain drain, results in the loss of some highly trained or qualified individuals. The social impact of displacement has not only reduced the region's economic potential (Cerovic and Beaton, 2017), but it has also tapered technological innovation in the region (Lozano-Ascencio and Gandini, 2012). This situation is reflected in the region's low output of patents and publications (Ciocca and Delgado, 2017) and diminished access to high-quality education (Busso and Messina, 2020).

As a country with a long-standing internal conflict and deep social disparities, Colombia has historically had a high emigration rate, including many people who are earning or have earned their graduate degree in a STEAM field (Docquier and Marfouk, 2004; Özden, 2006; Docquier, 2014). Among these, on average only one of every three scientists trained abroad returns to the country, as most of them report not encountering the conditions to continue with their research or find opportunities for professional development (Meyer et al., 1997; Didou Aupetit and Gérard, 2009). As many scientists remain abroad, there is a loss of potential expertise and role models in STEAM careers for the Colombian youth. Thus, STEAM education could benefit and be highly nourished by the participation of science diasporas. Recent reports on science diplomacy for Latin America propose strengthening the scientific system by reconnecting scientists from the region living abroad (Gual-Soler, 2021) and promoting the internationalization of the scientific community and efforts throughout collaboration between nations (Lopez-Verges et al., 2021b).

Context: Education Inequality in Colombia

Colombia is a country of divides and one of the most unequal countries in the world (Alvaredo et al., 2018; Busso and Messina, 2020; World Bank, 2021). Economic gaps in income, territorial disparities in access to basic infrastructure and social disparities in access to opportunity are among the multiple inequalities affecting the life chances and wellbeing of Colombian children and youth. Inevitably, learning and educational opportunities

[1]https://www.clubesdeciencia.co
[2]https://www.scienceclubsint.org

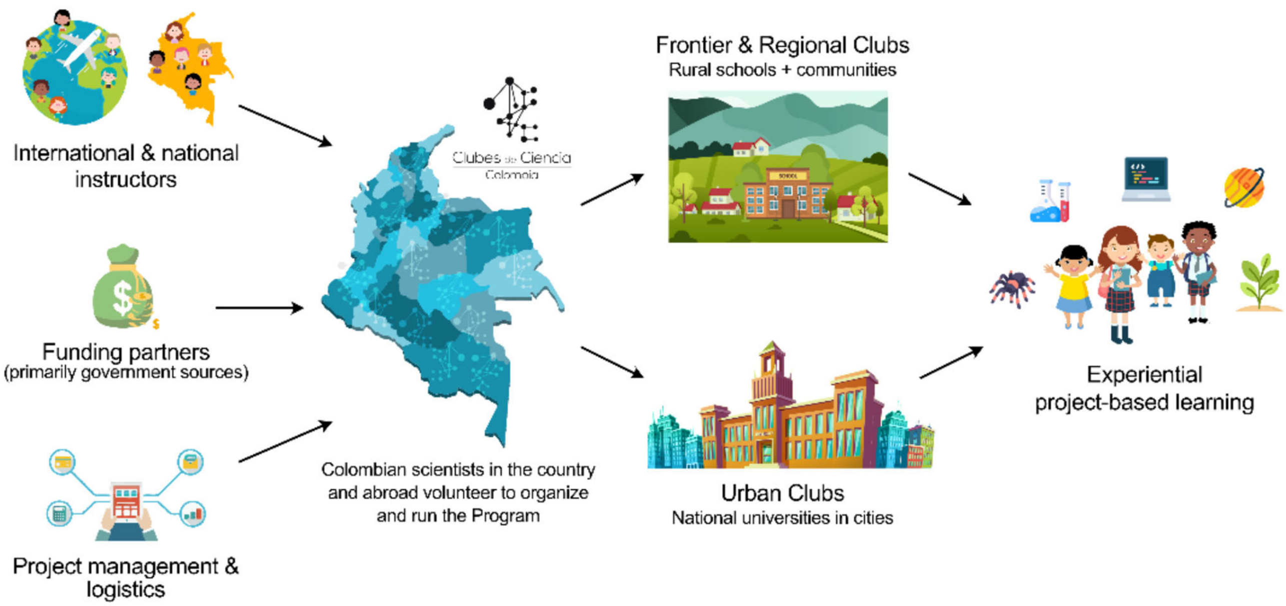

FIGURE 1 | Structure of the Science Clubs Colombia (SCC) program. The SCC program is a synergy between Colombian scientist living in the country and abroad, international and national instructors, funding agencies, a logistic team, and several other stakeholders that come together to deliver the different science clubs in both rural and urban areas of the country.

and outcomes are heavily affected under these conditions. In the long run, educational inequality also deepens the divides between social groups and territories. Recent indicators of student academic attainment and achievement, as well as schools' access to resources and teacher performance, reveal that Colombian children and youth from rural areas and low socioeconomic backgrounds have limited educational opportunities and poor academic outcomes (OECD, 2016a, 2019; Fundación Empresarios por la Educación FexE, 2021; World Bank, 2021).

In the last decades, Colombia has developed several policies to improve its educational system and expand its coverage. Despite these efforts, economic disparities, spatial divides, and other markers of disadvantage reinforce the still persistent educational inequalities (OECD, 2016b; World Bank, 2021). Additionally, the increase in public investment in education and the expansion of coverage have not been accompanied by systematic improvements in the quality of education. Several analyses of student performance in PISA tests and SABER national tests demonstrate that inequalities in students' academic performance are associated with their social ties. These ties include students' socioeconomic status, the type of school they attend (private or public), and the school's geographic zone (urban or rural) (Duarte et al., 2012; Gamboa and Londoño, 2015; Ramos Lobo et al., 2016; OECD, 2019, 2016a; Gomez-Gonzalez et al., 2021). Key factors causing educational disparities include the low quality of teacher training, the lack of a national curriculum, disparities in school funding—public and rural schools generally receive less funding—and selection bias in teacher-to-school assignments (Duarte et al., 2012; Fundación Empresarios por la Educación FexE, 2021; Gomez-Gonzalez et al., 2021; World Bank, 2021).

Rural Education and the Challenges of a Violent History

The urban-rural spatial divide needs special consideration because it reinforces extreme educational inequalities in Colombia. The territorial gap has a long history of marginalization of rural areas and their populations, particularly minority ethnic groups (Afro-Colombians and indigenous people), excluding them from access to basic services, employment, quality education, and other economic, social and learning opportunities (UNDP, 2011). Despite the efforts made by the government to close the urban-rural gap, the divide continues to evolve in complex ways. In 2020, the share of rural Colombians living in multidimensional poverty was 37.1% compared to 12.5% of urban dwellers (DANE, 2021). Likewise, educational inequality is more significant in rural areas. Indicators of educational attainment, for instance, reveal largely unfair conditions. Compared to students in urban centers, populations in rural areas receive fewer years of schooling (MEN, 2015) and have lower school enrollment and higher illiteracy rates (DANE, 2018). The added and devastating effects of climate disasters and the COVID-19 pandemic exacerbate this disparate scenario in many communities (Busso and Messina, 2020).

Furthermore, Colombian rural territories have been the most affected by the armed conflict (Gómez Soler, 2017), the longest civil war on the continent. The consequences range from political instability and altered economic and agricultural activities to direct violence, human displacement, and recruitment of

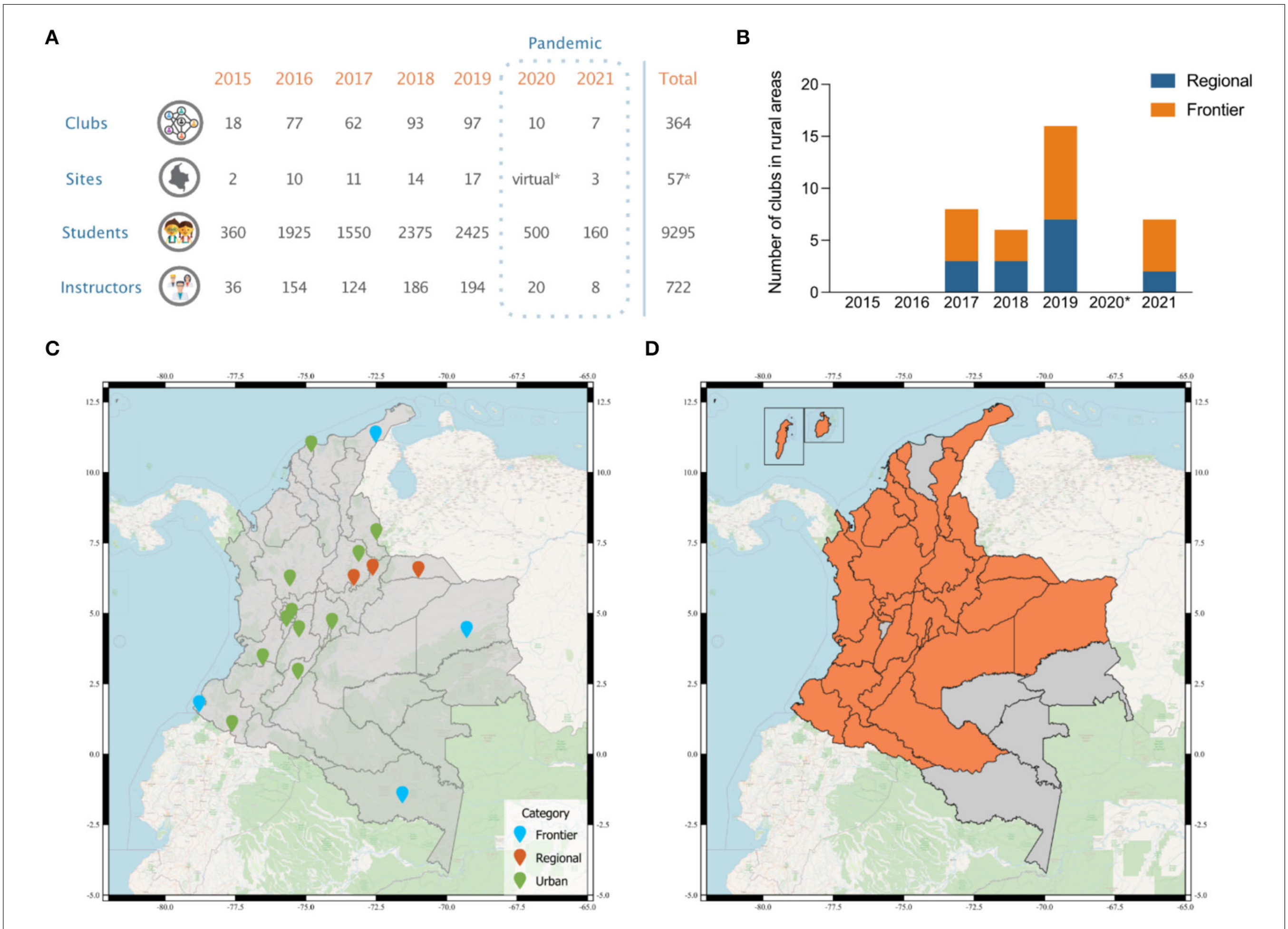

FIGURE 2 | Impact of the program (2015–2021). **(A)** Number of Science Clubs, participants, and sites during the seven years of the program operation in Colombia. *Denotes the virtual edition of the program that ran in 2020 due to the COVID-19 pandemic. The 2021 edition of the Program consisted of a hybrid implementation of the Clubs—"Science Calls You" edition. **(B)** The number of Science Clubs that have taken place in rural communities through the Regional and Frontier versions of the program. **(C)** Map of the geographical distribution of Science Clubs sites in Colombia throughout the history of the program. Colors indicate urban or rural (including both regional and frontier) locations. **(D)** Colombian departments reached during the 2020 Clubs at Home edition of the Program.

children and teenagers into armed forces. As an example of the extreme and direct effects, between 1990 and 2020, there have been 331 violent seizures or attacks in educational institutions by armed forces in Colombia (Bernal et al., 2021). Inevitably, these factors profoundly impact the possibilities and perspectives of Colombian rural youth.

Perspectives for Moving Forward

There is an inherent difficulty in transforming the multifactorial inequity outlined above, underlining the pressing need to enhance and diversify education opportunities that promote social mobility. Notably, occupational perspectives for low socioeconomic levels and rural communities are usually strongly constrained. There are not only lower expectations for higher education (Radinger et al., 2018), but there is also a lack of exposure to diverse options that allow children and youth to explore their interests and potential. In particular, science education is lagging behind. In Colombia and Latin America, there is much room for improvement in enhancing STEAM experiences for early ages, and this is particularly pronounced when considering equal opportunities for different genders, ethnicities, and socioeconomic groups. The SCC program considers that (1) accessing high-quality STEAM education is fundamental to address many of the inequities highlighted before, and (2) engaging the highly-qualified Colombian STEAM workforce in both the country and the diaspora, as well as international allies, is crucial to achieve equity in education.

SCIENCE CLUBS—THE SCC APPROACH

A Science Club is an intensive, project-oriented, 1-week workshop focused on developing technical and cognitive abilities in a wide array of research areas in STEAM fields [Clubes de Ciencia Colombia, 2022 (see text footnote 1); Science Clubs International | Science Education, 2022 (see text footnote 2);

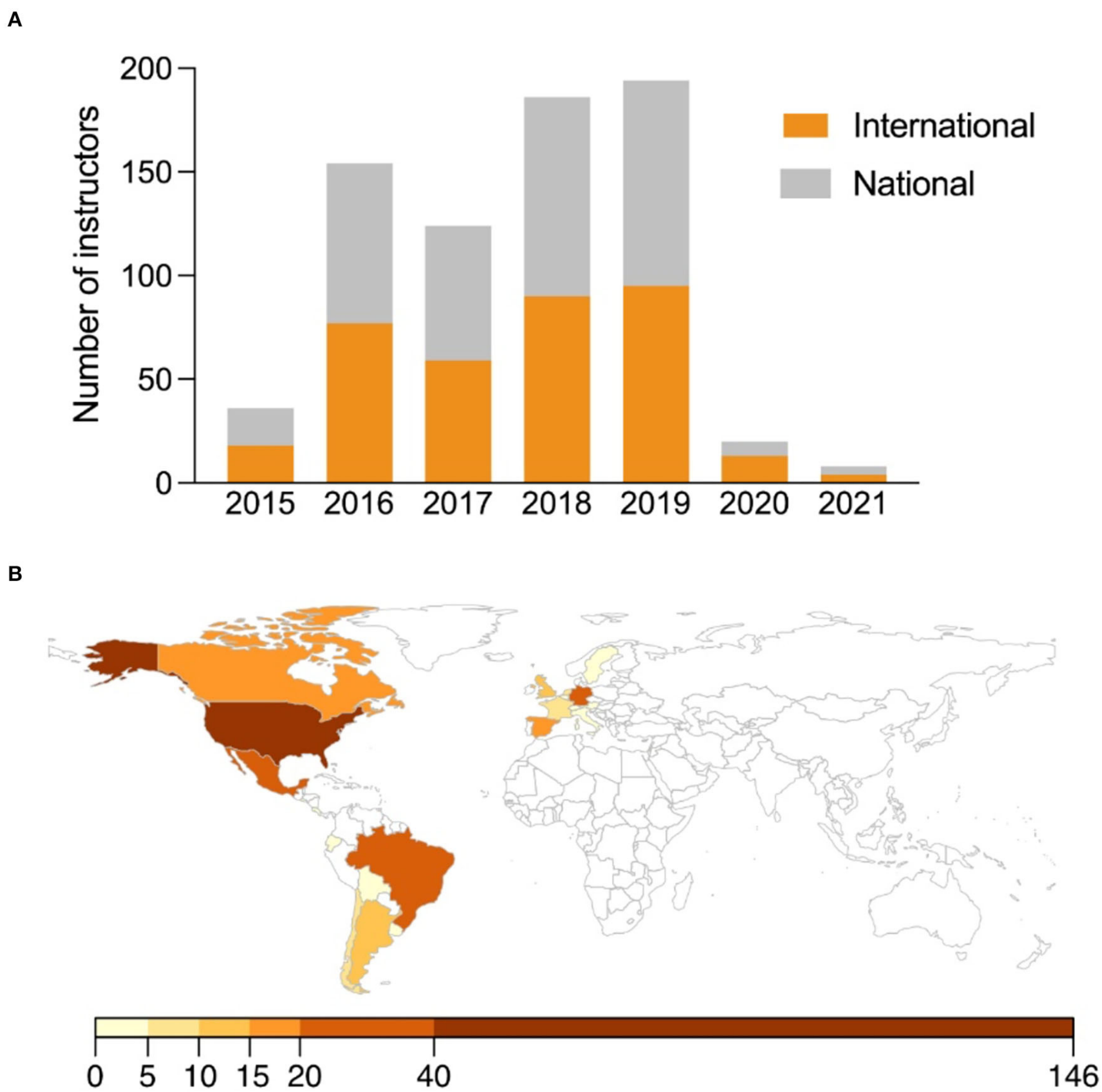

FIGURE 3 | International instructor involvement and distribution. **(A)** Total number of national and international instructors involved in the Program annually from 2015 to 2021. **(B)** Global distribution of international instructors defined by location of work or study during the year their corresponding Club took place.

Franco et al., 2019]. The Science Clubs aim to serve as a platform for young students to experience the world of research: conception of ideas, design, execution of experiments, and communication of results. Each Science Club is led by an international instructor, who is a graduate student or professional researcher affiliated with an international institution, in collaboration with an equally qualified local instructor based in Colombia (**Figure 1**). Project-based learning (PBL) is the essence of the instructional approach of the Science Clubs. This approach supports extended inquiry processes, engaging students in real-world problem solving, and providing meaningful and active learning opportunities (Jones et al., 2004; Helle et al., 2006; Capraro et al., 2013). In the Science Clubs, students are actively involved in the learning process through exploration, experimentation, and collaboration. Combining STEAM and PBL, Clubs are designed to foster creativity, critical thinking, and the development of skills students can apply to solve problems in their communities and local contexts. This approach has been applied across the *Science Clubs International* network in multiple countries, including Colombia (Bravo-Mosquera et al., 2019), Mexico (Lengeling and Jinich, 2019), Bolivia (Ferreira et al., 2019), Brazil, Peru, Ecuador, Paraguay, and Spain (Hernandez-Lopez et al., 2021).

The Science Clubs carried out in Colombia are geared toward teenagers ranging from 13 to 17 years old, who are students of public middle schools and high schools. Given

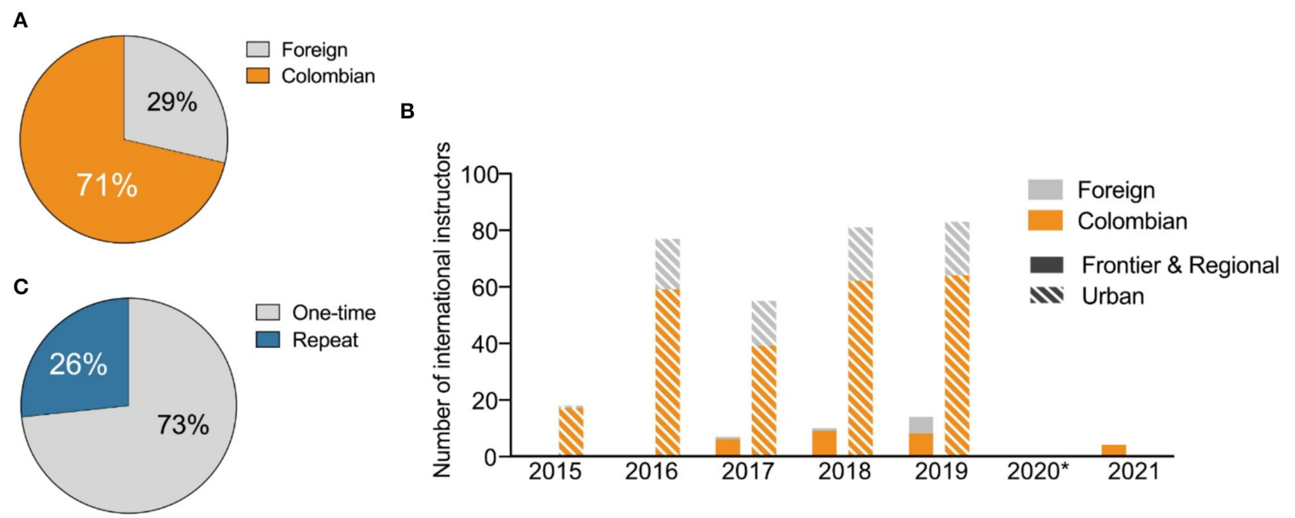

FIGURE 4 | Engagement of the Colombian diaspora. **(A)** Percentage of international instructors that are Colombian citizens vs. citizens of other countries ("foreign"). **(B)** Visualization of the proportion of international instructors involved in Frontier, Regional, and Urban versions of SCC who are Colombian citizens vs. foreign. **(C)** Percentage of international instructors who have participated in the Program for multiple years.

the country's vast cultural and social diversity, SCC divides the Clubs in three large categories—Urban, Regional, and Frontier (**Figure 1**). Most Urban Science Clubs have historically been co-organized with the "Tecnoacademias" Program from the Colombian National Technical Training Service (SENA). They take place in cities and occur in partnership with local universities that lend their facilities to host the workshops. In contrast, the Regional and Frontier versions take place in rural regions across the country. The Frontier Science Clubs focus on working with students in remote and borderland communities located in departments like Amazonas, Nariño, Vichada, and La Guajira. These Clubs have traditionally been financed through an alliance with the Colombian Ministry of Science and Technology. Finally, the Regional Clubs' primary goal is to serve rural communities all over the national territory in partnership with local authorities and organizations. The Regional and Frontier Clubs look for meeting needs and interests specific to each location and community (Buitrago-Casas et al., 2020). SCC achieves this objective by promoting the exploration of local talent and resources, acknowledging existing ancestral and communal knowledge, and encouraging the adaptation and appropriation of new knowledge while sparking curiosity and creativity in students.

RESULTS AND PROGRAM OUTCOMES

Reach of Science Clubs Colombia

Since its first edition in 2015, SCC has organized 364 Clubs impacting the lives of over 9,000 students across 57 sites in Colombia (**Figures 2A,B**). Whether in urban or rural areas, most of the students come from public schools, and many from low-socioeconomic status households, with limited access to high-quality education. Led by 722 instructors, the Clubs have covered a wide variety of STEAM topics: food science, biomedical engineering, artificial intelligence, conservation, agriculture, applied math, astronomy, biotechnology, social sciences, genetics, nuclear physics, and many others. SCC has reached students from 28 out of 32 Colombian departments (**Figures 2C,D**), despite the many inequities students face in both urban and rural settings. In particular, 37 Science Clubs have occurred in rural communities during the Regional and Frontier versions of the Program (**Figures 2B,C**). These communities are located in areas at risk of failing infrastructure, food insecurity (e.g., Guajira), and different levels of involvement in armed conflict (e.g., Amazonas, Arauca, Nariño, and Vichada).

Engaging the Colombian Diaspora

SCC targets the science diaspora and its networks to connect local scientists and students with international researchers. To achieve this goal, at least one instructor based at an international institution is involved in each club. The volunteers coordinating the program advertise the call through social media and international channels reaching researchers abroad. Applications are received via an online platform, and a systematic process is conducted to select the scientists who will travel to Colombia as instructors. To date, 356 international and 366 national instructors have taught a Science Club with consistent international and national participation throughout every edition of the Program (**Figure 3A**). In total, 49.3% of instructors worked or studied abroad the year they participated in the Program. These instructors were based in 22 different countries across North, Central, and South America; and Europe (**Figure 3B**; **Supplementary Table 1**). Notably, 75% of international instructors worked or studied in 5 countries: Spain (5%), Mexico (6%), Germany (9%), Brazil (11%), and the United States (44%). This diverse geographic representation allows the program to incorporate a wide variety of perspectives and teaching styles.

While the international instructors were located worldwide, 71% of them were part of the Colombian diaspora (**Figure 4A**). That is, they are Colombian citizens who now work and study outside of Colombia. This distribution highlights the high interest amongst the diaspora to return and contribute to the development of the country. An essential aspect of the program is the opportunity for instructors to travel to the locations where the Clubs take place (**Figure 2C**). Thus, scientists from the Colombian diaspora can witness the critical issues affecting local contexts and learn from their interactions with students and communities. Visiting the cities or regions where the Science Clubs are held, the instructors have the opportunity to get to know a new community or place, and to immerse themselves in the culture and reality of the locals. These opportunities create spaces that foster the exchange of knowledge, experiences, and worldviews, making it clear that science is a universal language and an effective tool to generate alliances and strengthen the social fabric. The instructors travel with the intention of teaching yet find themselves possibly also being students and raising their awareness about realities that are starkly different from their day-to-day lives. These experiences are vital for Regional and Frontier Clubs, which historically attract international instructors who are primarily Colombian citizens (**Figure 4B**; **Supplementary Figure 1**). At the same time, each Science Club experience is also a networking opportunity between instructors, school teachers, local leaders, and students. As a result, many instructors of the diaspora leave the Program with a renewed desire to engage in solutions to Colombian's most pressing issues. In fact, 27% of international instructors have returned to teach a Science Club one or more times (**Figure 4C**).

Adapting to a Changing Global Landscape

SCC relies on international collaboration to achieve its goal of providing access to high-quality STEAM education. This project-based learning program was designed to be conducted in person. During the first 5 years, the program grew in numbers and impact without interruptions. As a result, the program was heavily affected by the onset of the COVID-19 pandemic. Health and safety concerns, the redistribution of government funding to face the pandemic, international travel restrictions, and local mobility restrictions led to an interruption of traditional programs. Nonetheless, the program was able to adapt and create a new "Clubs at Home" version of the Science Clubs. In this version, instructors designed 4 week-long modules, including pre-recorded lectures and worksheets with experiments to be performed at home with readily available materials. Due to the lack of geographical constraints, these Clubs were open to students all over the country. We were therefore able to reach a higher volume of students, 500 to be precise, with only 10 Clubs (**Figures 2A,B**). Additionally, we introduced the methodology to students from 12 new departments, primarily in urban areas (**Figure 2D**). However, this first foray into remote learning also highlighted the disadvantages and lack of infrastructure faced by students in rural areas of the country.

The lack of equipment, wireless connectivity, and in some cases, reliable electricity severely limited the ability of former participants in the Regional and Frontier Clubs to access any virtual platform. To address these challenges, the program pivoted once again in 2021 with an innovative hybrid solution for these populations—the "Science Calls You" Clubs (Avendaño-Uribe, 2021). A few instructors from the "Clubs at Home" version were asked to come back and reuse previously created videos and content. Students received personalized kits consisting of a modified old-school cellular phone (not smartphones), learning guides, worksheets, notebooks, and all materials necessary to carry out all experiments and activities. Students and instructors would communicate through calls using a voice-only platform and the phones throughout the 4 weeks of the Clubs. As usual, 50% of the instructors were international (**Figure 3A**). The selection of the clubs' topics matched the needs of each community in the fields of agriculture, social and data science, math, and hydrology. The targeted communities were located in the Isipha and Wayma communities in La Guajira and Carcasí, Santander, for a total of 7 Clubs and 160 students (**Figures 2A,B**). Some of the instructors were able to travel to La Guajira in person.

The "Science Calls You" version sought to implement a more sustainable approach for these communities through four key strategies to continue the program in future editions. (1) Obtaining funding to perform upgrades to the local infrastructure where necessary that would outlast the Clubs. (2) Local teachers helped conduct the Science Clubs by providing space in their classrooms and guiding the students toward the successful execution of all proposed activities. (3) Study guides and worksheets were designed to fit the cultural norms and practices of the region and created with important contributions in ethno-education by local teachers. (4) Some of the Clubs' activities were aimed at providing long-term solutions for these communities. For example, students and teachers established a garden in their indigenous school at the Wayuu community of Ishipa, located in La Guajira, a department plagued by droughts and food insecurity. These efforts once again underscore the importance of and potential for collaboration between communities in Colombia and the scientific diaspora.

DISCUSSION

Possibilities for the Scientific Diaspora Through Science Clubs Colombia

SCC has been successful in mobilizing the science education ecosystem in the country. Thanks to more than 300 organizations and over 700 scientists working together, it has been possible to promote the participation of scientists from different nations in high-quality science education in the Latin American region and Colombia. These articulated efforts have demonstrated that the science diaspora can be actively connected to STEAM education in Colombia.

In this report, we describe how SCC promotes high-quality STEAM education adapted to the needs and context of the country while contributing to robust international scientific networks and collaborations as a potential diplomatic outcome. We illustrate the expansion of the program deliberately oriented toward reducing unequal opportunities by reaching diverse communities and a broad geographic range within the country. Additionally, we discuss several characteristics of the program and its development that underline its potential value for strengthening international bonds. Those international relationships are cornerstones of potential diplomatic structures and reveal the role of the scientific diaspora in STEAM education.

First, we show the consistent participation of researchers based abroad that have teamed up with researchers living in Colombia throughout the history of the program. This collaboration suggests a significant contribution to strengthening international ties between scientists. Second, the participation records indicate that most international instructors are Colombians, revealing interconnectedness and commitment among the Colombian scientific diaspora. Third, the sustained growth in the number of instructors and the probability that they repeat the experience (26%) indicates that the program is attractive and engaging for Colombian and non-Colombian international researchers. Fourth, the involvement of different global regions, including Europe, North and South America, shows the broad-reaching impact of the Science Clubs project. This program and similar initiatives propose a valuable link between STEAM education and science diplomacy that should tackle social, political and technological issues in Latin America and worldwide.

Harnessing Science Diplomacy to Integrate STEAM Education in Latin America

Science diplomacy has included a wide range of topics and negotiation themes with the goal of tackling current challenges such as food security, climate change, Antarctic governance, and public health (Turekian et al., 2014). In several nations, science diaspora communities already play an integral part in facilitating solutions to such global challenges (Burns, 2013). Within Latin America, experts on science diplomacy have recommended the "articulation of networks of scientists abroad to strengthen national science systems and foster brain circulation" (Gual-Soler, 2021). Nonetheless, the inclusion of the science diaspora into STEAM education as a potential outcome for science diplomacy has received minimal attention in the region. The SCC Program is based on the premise that organized scientific diasporas could benefit national STEAM education and could promote scientific collaboration between nations.

Although SCC is not a science diplomacy initiative, the program is built on interactions between stakeholders from different nations—multilateral organizations, research institutes, universities in Colombia and abroad, organizations in the public and private sector, civil society, and other institutions. It engages the Colombian scientific diaspora, local scientists and institutions, and international allies to provide high-quality science education to historically marginalized communities. These activities require new network building with the purpose of providing STEAM education. Furthermore, they may lead to a secondary diplomatic outcome—strengthening international relations to impact science education on a national and regional scale. Additionally, members of the scientific diaspora who participate in the program stay connected throughout spin-off projects, and formalize partnerships and alliances with both local and national governments that may foster long-term collaboration between international stakeholders. These activities lead to new network building within STEAM education, research, and development.

Following the creation of the International Mission of Wise Men and Women (Pavas and Arzola de la Peña, 2019) and the establishment of the first Ministry of Science, Technology, and Innovation (Minciencias), Colombia has set the new strategic objective of positioning, making visible, and articulating the sectors of science, technology, and innovation at the international level. The plan is to create a national science diplomacy strategy with nodes in nine Latin American countries (including the neighbors Brazil, Panama, and Peru) (Gual-Soler, 2021). This governmental strategy focuses on training and capacity building in science diplomacy, both within the government and other entities/actors. Notably, it demands greater coordination between the diaspora and the Colombian scientific communities. The positioning of Colombia in South-South alliances is also envisaged, considering its entry into the OECD in April 2020 and its potential to support countries in the region with lower capacities (Gual-Soler, 2021). In the long-term, the SCC Program is positioned to become a key partner in this mission given its existing engagement with the Colombian diaspora, governmental institutions, and international partners.

We argue that articulating science education into the diplomacy agenda can start with mobilizing the science diaspora from the Global North and South to support STEAM education in less-favored areas. There is an additional need to increase efforts tackling the multiple inequities that have intensified in recent years in Latin America, particularly in Colombia. As the analysis of SSC reveals, this program has enabled the mobilization of the science diaspora, promoting scientific vocations, and promoting science education as a pillar of transformation in society. The SCC model has been replicated in different contexts of Latin America, Spain, and the USA; it can inspire similar efforts in other regions where science education is still a shortage for underrepresented communities such as Africa, Asia, and Pacific-Oceania.

Particularly, the implementation of the Frontier and Regional version of our program highlight the need for STEAM education in rural areas and the potential for engaging scientific diasporas in the process. Little research has been done on the impact of mobilizing human capital, including established researchers and graduate students, as promoters of scientific vocations or STEAM education in rural areas. Importantly, through this scientific experience the students gain insight on how STEAM training could foster transformation in their communities.

Key Challenges

A connected and active science diaspora engaged in STEAM education can lead to scientific diplomacy outcomes. Keeping science diaspora engaged into STEAM education promises long-term benefits for high-quality education, such as the

Science Clubs Colombia program. However, this promising approach bears some challenges that deserve special attention, as outlined below.

First, human capital is a major challenge for the execution and sustainability of the program. The project's rapid expansion gives rise to intrinsic demands for large-scale project management. Major time and efforts are invested in recruitment, logistics, communication, fundraising, and pedagogical support. Given that the program's management is taken over by a group of <15 volunteers who are full-time scientists or doctoral candidates, consistent and extended commitment of team-members is extremely challenging. Incentives in the form of logistic and/or financial backup for the researchers promoting grassroots initiatives like *Science Clubs* would guarantee the long-term sustainability of these programs.

A second key challenge is sustaining a robust and reliable financing scheme. Historically, a combination of public and private institutions has funded the program. However, none of these entities provide constant financial support, meaning that fundraising is a yearly task for the volunteer team. Incoming contributions rely on rigorous proposal writing and the availability of funding bodies each year. Considering the large scale of the program, this also results in tight budgets and the need to cut down on features of the program, like paid educational staff or longer duration of the projects, which could further boost pedagogic quality. In response to this challenge, in 2021, *Science Clubs Colombia* aimed at incorporating local teachers in the workshops and designed follow-up activities that provide continuity to the learning experience. However, financial sustainability remains a challenge.

Another opportunity for improvement is attracting researchers from a broader geographic range to participate as international instructors. This challenge has intrinsic difficulties associated with language—the workshops are held in Spanish—, and is naturally biased toward countries that have a historical connection to the program or where a large number of Colombians seek higher education, as is the U.S.A. However, Science Clubs and the associated scientific network would benefit from further strengthening participant diversity. Notably, Latin America has created academic exchange and mobility impacting the scientific ecosystem (Lopez-Verges et al., 2021a). An increasing number of Colombians engage in doctoral and post-doctoral research experiences abroad, including countries such as Spain, Mexico, Argentina, Germany, Chile, France, and Peru (Peña Castañeda, 2019), which should be reflected in the program. The feasibility to support researchers from various countries, primarily those more geographically distant, relies on fund availability and therefore goes hand-in-hand with the challenges described above.

CONCLUDING REMARKS

This report describes elements of a grassroots science education program that leads to a proven, scalable and reproducible outcome of connected science diasporas and their engagement in STEAM education. The model of SCC program can be replicated in different contexts and children will benefit from a high-quality scientific education program that leads to international collaboration and long-term networking for promotion of STEAM careers.

This is the first brief research report where more than 700 scientists over 7 years have participated in constructing a network that impacts children and young students in rural areas of Colombia. This paper intends to inspire other STEAM programs that convene the science diaspora to work hand in hand in collaborations to improve the quality of education in Latin America. It is also a call for future science diplomacy frameworks in the region to include STEAM education initiatives that mobilize the science diasporas as a critical global strategy to increase scientific and technological capacity. Additionally, we exemplified the importance of engaging science diasporas in science education as a mobility experience that potentially could benefit Global South and Global North countries. Finally, engaging science diasporas to temporarily return to their countries of origin to support rural education in disadvantaged communities has potentially a long-term impact on the scientific vocations of children and youth—an area of interest outside of the scope of this paper that we will investigate further. Thus, promoting learning and collaboration between local and international networks impacts the Latin American scientific ecosystem.

The promise of a future where the science diaspora actively contributes to STEAM education, mobilizing, and collaborating with different national educational programs is not far from reality if science diplomacy programs and public policy recommendations include STEAM education in the agenda. Integrating science diasporas in STEAM education could potentially have outcomes that impact the long-term dynamics of science diplomacy and could help to bridge educational inequalities. The idea is to include highly trained international scientists in the national education system so that schools become small-scale science laboratories, where teaching, learning, and research potentially improve experiential science education. We seek an education where teachers, community and students can articulate efforts to tackle cutting-edge problems using STEAM skills and abilities to permeate public education systems.

DATA AVAILABILITY STATEMENT

The data analyzed in this study is subject to the following licenses/restrictions: the dataset of volunteer scientists is not openly available and we reserve the right to share it. In our research we do not use names or personal identifications. We have taken the adequate provisions to protect the privacy of subjects and to maintain confidentiality of data. Requests to access these datasets should be directed to ScienteLab/Clubes De Ciencia Colombia, conocimiento@scientelab.org.

AUTHOR CONTRIBUTIONS

BA-U conceived the idea, led the submission and writing process, and he coordinated the team to structure the paper.

AP created most tables and figures, wrote the approach and results section, and led the rewriting of the subsequent drafts. AL-B wrote the context and included scientific references for the academic content of the paper. LF led the edition, part of the structure, and wrote many contributions along the paper, including introduction, context, results, and discussion. EC conducted data mining and organization of the raw data from 7 years of the program. JA created the maps and contributed to finalized versions. AH-M contributed to the introduction of the paper. JB-C helped with final formatting, edition, and proofreading. All authors contributed to the article and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frma.2022.898167/full#supplementary-material

Supplementary Figure 1 | Percentage of international instructors in Frontier/Regional and Urban versions of the Science Clubs Colombia Program who are Colombian citizens.

Supplementary Table 1 | Distribution of international instructors per country.

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PERSPECTIVE
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Recognize and Alleviate a Resource Management Conundrum Facing Science Diaspora Networks

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Increasingly, science diaspora networks are managed by formal organizations such as embassies or non-profit organizations. Researchers have studied these networks to understand how they influence international collaborations and science diplomacy, and to determine which network activities foster those outcomes and which do not. In this perspective, we suggest that many of these network organizations confront an underappreciated conundrum for managing resources: organizations with few resources must learn how to obtain more resources despite lacking means to do so. To substantiate our suggestion, we do the following. We review exploratory results from a study of network organizations that indicate that these organizations generally lack resources, learn too little from each other, and struggle to overcome the resource conundrum. We also show that this conundrum is expected from organizational theory based on bounded rationality. To help organizations confront the issue, we do the following. First we provide a new database of operating science diaspora networks. We encourage managers of network organizations to use it as a resource to identify peers with whom to regularly exchange knowledge about securing resources. We also suggest that other scientific organizations should infuse network organizations with fresh resources. Ultimately, we urge all relevant stakeholders to recognize that the conundrum results not from the shortcomings of individual managers, but rather is a legitimate organizational phenomena that must be addressed by organizational design.

Keywords: knowledge network, resource management, science diplomacy, organizational analysis, brain circulation, network approach model, bounded rationality

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INTRODUCTION

Highly educated and skilled researchers in STEM (science, technology, engineering, and math) increasingly emigrate from their countries of origin to pursue educational and career opportunities elsewhere (Anand et al., 2009; De Domenico et al., 2016; Netz et al., 2020). Often these individuals are described as living in diasporas (Barré et al., 2003; Séguin et al., 2006; Meyer, 2019). Researchers use the terms "diaspora knowledge networks" and "scientific diaspora networks" to describe the social, economic, and political groups that have formed to link these transnational and migrant populations of professional and scientific communities (Meyer, 2001; Brown, 2002; Barré et al., 2003; Mahroum et al., 2006).

Increasingly, diaspora networks are managed by formal organizations (Gamlen, 2014; Gamlen et al., 2019). Sometimes countries create organizations within their foreign embassies and consulates to manage a network in a host country. For instance, the Office of Science and Technology Austria, Washington (OSTA) is a department of the Austrian Embassy to the United States. OSTA manages its Research and Innovation Network Austria, comprised of Austrian researchers across North America. Sometimes international organizations create subunits to connect networks of members. For instance, the Marie Curie Alumni Network has 33 local chapters to connect current and previous recipients of Marie Skłodowska-Curie Actions funding. Sometimes emigres in a host country create non-governmental organizations to provide bank accounts, listservs, bylaws, and managerial roles for their network. One example is the Italian Scientists and Scholars in North America Foundation, which connects more than 3,000 primarily Italian researchers who live in North America.

Many of these network organizations confront a resource management conundrum. They work with little or transient budgets, time, and staffing. We recently completed an interview study of managers from 21 organizations (Butler et al., 2022). Our results indicate that managers recognize this resource scarcity, that they want to improve their situations, and that they often cannot begin this process due to lack of resources. The conundrum for organizations with few resources is to learn how to obtain more resources despite lacking the means to do so.

In this Perspective, we argue that this conundrum should be recognized, further studied, and alleviated as a legitimate organizational phenomenon confronting diaspora network organizations. Our strategy is as follows. First, we provide a new database of extant science diaspora networks to update previously published lists (Meyer and Brown, 1999; Brown, 2002; Meyer and Wattiaux, 2006). The database is a resource for further studies of network organizations. Next, we overview exploratory results from our recent work indicating that network organizations confront the resource conundrum (Butler et al., 2022). We then show that the conundrum is expected from organizational theory. We close with suggestions for how different kinds of stakeholders could help alleviate the conundrum.

A DATABASE OF DIASPORA NETWORK ORGANIZATIONS

We define a diaspora network organization as a formal organization that manages a diaspora network. A diaspora network connects people of a particular national or regional background in a host country or region. A network organization has at least one person who manages the budget, activities, communications, and resources for the network. Commonly they have bylaws and can be subunits of parent organizations (e.g., of embassies), non-governmental organizations, clubs, etc. Network organizations for science in particular aggregate scientists for the purposes of professional development, collaboration, or community building (Brown, 2002; Burns, 2013; Tejada, 2013; Bonilla et al., 2018).

We provide here an updated database of active science diaspora network organizations, with links to their websites (see **Supplementary Table 1**). This database updates similar efforts published earlier (e.g., Meyer and Brown, 1999; Brown, 2002; Meyer and Wattiaux, 2006; Echeverría-King et al., 2022). For our recent study, we created an initial list of active networks and continued to iterate it after the study was completed (Butler et al., 2022). We have found 49 active networks through literature reviews, web searches, and word of mouth, and there are likely many more in existence that were not captured by our study.

Table 1 summarizes the geographical, structural, and lifespan diversity of the networks. All authors reviewed networks' websites and unanimously grouped networks into categories by Region, Structure, and Age. Compared to other regions, there is a disproportionately large number of networks with ties to European countries in the database, for which we suggest two potential explanations. First, there may be collection bias by our North American-based research team, as there are many European networks in North America. Second, the disproportions may reflect real disparity in the prevalence of diaspora networks across regions, with those from or in high income countries in the global north more able to develop networks compared to those from or in low and middle income countries. We encourage further iterations of the database to capture more networks across more regions. We also encourage further research to investigate the reality and causes of this apparent regional disparity.

CORROBORATION OF THE CONUNDRUM

Between January 2021 and March 2022, we conducted an exploratory study of scientific diasporas networks and those who manage them. We interviewed managers from a sample of 21 networks, which varied in network size, type of organization, host countries, countries of origin, aims, etc. We asked them to characterize how they conceptualize network success, network relevance to diplomacy, current challenges, and future plans. Full methods and results can be found in our recent report (Butler et al., 2022). Here we describe the resource management conundrum common to many diaspora networks. We found this sentiment existed across all three inductively-coded themes of Challenges, Success, and Future.

The conundrum for organizations with few resources is to learn how to secure more while lacking resources to do so. One of the most basic ways managers can do this is to regularly interact with other managers from peer organizations to share operational knowledge and tactics. Responses to our interview questions indicated that many managers struggled to find resources, especially time, to accomplish such tasks.

Challenges

The majority of interviewees cited few resources as a major challenge to the operation of their networks. In many cases, managers described significant amounts of work completed on minuscule budgets, with little or no infrastructure or staff

TABLE 1 | Summary of science diaspora networks[†].

	Region (49)		Organization structure (49)	
	Region of origin	Host region	Volunteer*	8 (16.3%)
Africa	0 (0.0%)	0 (0.0%)	NGO**	27 (55.1%)
Asia^	10 (20.4%)	5 (10.2%)	Govt.***	14 (28.6%)
Europe	25 (51.0%)	3 (6.1%)	**Age of the organization (42)**	
Latin America	8 (16.3%)	1 (2.0%)	>20 years	17 (40.5%)
North America^^	0 (0.0%)	23 (46.9%)	19–10 years	12 (28.6%)
SWANA^^^	3 (6.1%)	0 (0.0%)	10–5 years	8 (19.1%)
World	3 (6.1%)	17 (34.7%)	<5 years	5 (11.9%)

[†] *All percentages are computed in relation to the number of organizations represented in parentheses. Compared to Region and Organization Structure, Age of Organization summarizes fewer total organizations due to inability to determine ages for seven organizations.*

^*Includes Australasia.*

^^*Excluding countries commonly classed in Latin America.*

^^^*South West Asia/North Africa.*

* *Volunteer indicates organizations that note no larger organization governing them and no not-for-profit status identified.*

** *NGO or non-governmental organizations, are organizations with not-for-profit status or that were founded as part of a parent NGO.*

*** *Govt. or governmental groups founded are those founded by federal directive or under the purview of a federal body.*

to support the missions of their network organizations. As a result, managers reported spending their time accomplishing highly programmed tasks that they have experience with, such as managing listservs, organizing events, and addressing member needs. This result was especially common for managers of organizations younger than 5 years. Managers of older organizations noted that they hardly interacted with their peers at similar organizations, and they worried that they were reinventing organizational structures and processes rather than sharing knowledge. A majority of interviewees across all organizations voiced feelings of isolation given no, little, or rarely sustained interactions with managers at peer organizations. Managers with comparatively greater resources, especially funding from parent or outside organizations, reported disconnects between satisfying the needs of the funders and satisfying the needs of the network members. Relatedly, for managers of organizations that were older or had more resources, especially formal embassy connections, they reported being more likely to spend resources on science diplomacy to influence policy.

Success

Nearly all interviewees conceptualized success for their organizations as making connections, a result consistent with findings of previous studies on diaspora networks' objectives and types of engagement activities hosted (Brown, 2002). The more connections an organization helped foster, the more successful its managers judged the organization. Managers most commonly talked about making connections between the individual members of their particular network, e.g., to foster friendships, research collaborations, and mentor/mentee relationships. They also discussed connections between network members and representatives from scientific or governmental organizations (e.g., program managers at funding agencies, staffers and diplomats in governments and embassies, and hiring managers at universities, non-profits, or firms). These connections then fostered the professional development of network members. Fewer than five interviewees discussed making connections with peer managers at other network organizations as markers of success.

Future

When asked about the future of their networks, most interviewees expressed desires to increase and strengthen connections, most commonly with their members, and sometimes with relevant governments from countries of origin to increase their influence and acquire more support. Interviewees recognized the impact they could have by working with other networks, especially as new global scientific challenges arise, and were interested in sharing operational knowledge with their peers. Many groups asserted that they wanted to form inter-network connections in the future.

Altogether, these results indicate that managers are acutely aware of their resource scarcity, and that they can rarely spend their resources to learn organizational processes from their peers. The results also indicate that there are opportunities for these organizations to help alleviate this problem. They already characterize organizational success as fostering connections, a criterion that can be extended to include explicitly making connections with peer managers in other networks to learn organizational processes for, among other things, securing resources. Furthermore, if these groups more regularly shared information with each other, they could strengthen their diplomatic advocacy and ease burdens of having to individually create structures and techniques to address similar issues.

These results are exploratory and suggestive, and further studies are needed to test the extent to which network organizations confront the resource management conundrum and to assess the scope and impacts of the conundrum. We next suggest that such efforts would prove fruitful, as the conundrum is expected from organizational theory.

THE CONUNDRUM FROM THEORY

As a general organizational phenomenon, the resource management conundrum is a consequence of organizational theory based on bounded rationality (Simon, 1991, 1997; March and Simon, 1993). In this theory, people and organizations are agents of bounded rationality and thus have imperfect knowledge of the world. They curtail their searches for solution to problems when they have developed satisfactory—rather than optimal—solutions, and they develop standard procedures, routines, or programs to deal with recurring problems. The theory of bounded rationality is widely used to characterize human and organizational learning in fields such as organizational studies, economics, cognitive psychology, and political science (Jones, 1999; Wheeler, 2018).

The conundrum depends on two regularities of the theory related to how organizations learn new procedures. First, the more an organization is dissatisfied with its procedures to address a need, the more likely it is to search for better procedures (March and Simon, 1993, 194). It is often beneficial to search similar but distinct organizations, as doing so often requires fewer resources than developing and testing new procedures *de novo*. Second, managers tend to spend resources on procedures that are highly programmed and not on those that are highly unprogrammed (March and Simon, 1993, 206–207).

An organization is more likely to get one of two outcomes from search and learning processes depending on the amount of its current resources, which can be mediated by the quality of its current search procedures. The more resources an organization begins with, the more probable it is to achieve the Getting Richer Outcome. The fewer resources an organization begins with, the more probable it is to achieve the Staying the Same Outcome.

Getting Richer Outcome: If an organization already has resources to search similar organizations for alternative procedures to secure resources, then it can learn from other organizations. The learning process will be more or less efficient depending on the organization's store of highly-programmed search and learning processes, which enable more efficient use of resources for search and learning. If an organization lacks good search and learning procedures, but it has surplus resources, it will spend some of that surplus on highly-unprogrammed, likely inefficient, searches. In either situation, the organization increases its chances to find better alternatives to its current procedures for securing resources.

Staying the Same Outcome: If an organization lacks resources to search and learn from other organizations, then it cannot search and learn from other organizations. Even if it has highly programmed and effective search procedures, but not the resources to use them, they are of no practical use to the organization. And if an organization lacks good search procedures and resources, with no resources it cannot develop better procedures or perform even inefficient searches. In either situation, the organization cannot learn from other similar organizations. It will likely persist at its current resource level.

The conundrum for organizations with few resources and a desire to secure more resources is to learn how to avoid the Staying the Same Outcome. Alleviating the conundrum is neither a trivial nor an obvious task, nor does it admit of a single solution.

DISCUSSION AND RECOMMENDATIONS

The network model of researcher diasporas has two functions. First, it describes emigre activity, as a diaspora's members connect to each other *via* regular communication channels (e.g., listservs, social media, etc.) that are characteristic of social networks (Meyer, 2001; Newman, 2003). Second, the model normatively indicates how emigres and their countries of origin and host countries should mutually interact (Mahroum et al., 2006; Tejada, 2013; Tejada et al., 2014; Bonilla et al., 2018; Radwan and Sakr, 2018). For this second function, diaspora networks are termed networks because doing so links them to a model of researcher migration that differs from the brain drain model (Brown, 2002; Séguin et al., 2006; Zong and Lu, 2017). The brain drain model implies that researchers who leave their countries of origin deprive those countries of benefiting from the expertise of the researchers. Conversely, the network model enables countries to treat their researchers abroad and the communities they host as resources for international knowledge exchange, economic development, and diplomacy (Meyer, 2001; Ciumasu, 2010; Burns, 2013).

Our discussion here corroborates but does not prove the expectation from theory that managing organizations for scientific diaspora networks face a resource management conundrum. Further research is needed. Nonetheless, we judge it likely that network organizations and their managers regularly contend with the Staying the Same Outcome.

Below we suggest three general strategies to alleviate the resource conundrum—one applicable to all science diaspora network stakeholders, one for network managers, and another for current and potential partner organizations (e.g., funding bodies, universities, and multilateral institutions). These strategies inform the normative aspect of the network model.

First, all science diaspora network stakeholders should recognize that the Staying the Same Outcome is a legitimate management conundrum. It results from resource constraints—not from manager shortcomings. In our interviews, managers often blamed themselves for not having the time or knowledge of their peers to reach out for ideas on how to secure more resources. Many also mistakenly worried that their organizations were unique in their scarcity of funding, time, and staff. There may also be discomfort in acknowledging to peers a need for ideas on how to successfully secure more resources. We hypothesize that if more people recognize that the conundrum is an expected outcome for organizations with few resources, and not the product of managers' shortcomings, then more people will be willing to discuss it and find strategies to alleviate it.

Next, network managers in particular can usefully turn unprogrammed search and learning activities into more highly programmed activities or routines. Rather than relying on happenstance interactions with their peers at similar organizations, managers would be wise to develop regular and structured practices for consistently exchanging ideas and knowledge about techniques to secure resources. To do so, they must revise their criteria of organizational success to include regular professional development specifically for managers *as managers*. They must also budget and protect some resources, no matter how small, to connect with and learn from their peers at other organizations. Such resources can be as little as 6 hours a year vouchsafed to call peers and talk about operational processes. A key aide to this effort is a list of networks from which peers can be identified (see **Supplementary Table 1**).

Finally, other organizations could fruitfully infuse network organizations with resources. Diaspora networks do not exist in a vacuum apart from other scientific organizations, with which their goals often align. Many funders, government and philanthropic alike, further science primarily by funding research projects. There are opportunities to fund more capacity-building projects for networks organizations. These projects could provide networks with resources to hire staff, develop and improve regular procedures, and secure larger and longer-term funding from additional funders. Scientist networks are resources for any country they interact with, including host countries. Funders in one country may usefully partner with peer funders in a second country to mutually support networks that span their borders.

Opportunities exist to strengthen diaspora networks and science diplomacy by supporting communities of practice among the managers of network organizations. This position is notably taken by EURAXESS, which focuses on European contexts and enjoys European Union (EU) funding to seed, support, and grow diaspora networks abroad. EURAXESS provides several guides for doing so (e.g., Mahmoud and Bodnarova, 2019). The EU is unique, but it is not the only multilateral organization that could support stronger communities of practice, especially for low- and middle-income countries (Séguin et al., 2006). Similar and additional efforts could be further supported by, for instance, the African Union, Organization of American States, and the United Nations *via* programs like Transfer of Knowledge through Expatriate Nationals (TOKTEN) and The World Academy of Sciences (TWAS). Additionally, as many diasporic scientists are part of the academic labor market, institutions such as the International Association of Universities can play animportant role in supporting the globalization of research and ducation (Welch and Zhen, 2008, Larner, 2015).

Science diaspora networks bring immense value to their members, partners, and diplomacy. An increasing array of actors are noticing that value. Current and future stakeholders should recognize and work to alleviate the management conundrum confronting these networks. Doing so will benefit science and diplomacy.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author.

ETHICS STATEMENT

Ethical review and approval was not required for the study on human participants in accordance with the local legislation and institutional requirements. Written informed consent for participation was not required for this study in accordance with the national legislation and the institutional requirements.

AUTHOR CONTRIBUTIONS

All authors contributed to the conception, design, and conduct of the project. AZ organized the database of networks. SE wrote the first draft of the manuscript. DB, BD, EG, IW, and AZ wrote sections of the manuscript. All authors contributed to manuscript revisions, read, and approved the submitted version.

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SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/frma.2022.898770/full#supplementary-material

Supplementary Table 1 | Database of scientific diaspora network organizations.

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RAICEX: A Successful Story of the Spanish Scientific Diaspora

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RAICEX (Red de Asociaciones de Investigadores y Científicos Españoles en el Exterior), the Network of Associations of Spanish Researchers and Scientist Abroad, consists of more than 4,000 Spanish researchers distributed in 18 countries in 5 different continents. RAICEX was established in July 2018 by 15 foundational members: the associations of Spanish Researchers in the USA, México, Ireland, Sweden, Denmark, France, Italy, Japan, Australia, China, UK, Germany, Switzerland, Belgium, and Norway. Since then, 3 more associations have joined: Emirates, Netherlands and South Africa. RAICEX was born with the main goal: "*promoting the exchange of experiences and knowledge between Spanish researchers and scientists abroad and all the stakeholders of the Spanish System of Science, Technology and Innovation (SECTI), serving as an advisory body, information channel and catalyst for international relations in scientific matters, contributing to the progress of science.*" Their main objectives are: (1) to provide support to researchers and scientists in mobility and personal development, offering training, information and guidance, as well as providing contact with all the other associations that make up the global network; (2) to disseminate and give visibility to the value of Science and the work of researchers and scientists, promoting communication of the advances of knowledge in all areas of society; (3) to promote international relations and cooperation between researchers / scientists and public and private organizations, from a global perspective; (4) to share the acquired knowledge and experience in different research and science systems abroad to advise, provide feedback and contribute to the progress of the whole SECTI. In this Case Study a particular scenario of the Spanish scientific diaspora, including history, reasons for going abroad, and consequences for the Spanish R&D system, shall be introduced to readers. The impact that RAICEX and its foundational members have had in the Spanish National System since the creation of the first community in the UK by 2012 will also be discussed. RAICEX's activities range from providing advice to newcomers and carrying out science dissemination, to becoming an advisory body to governments and institutions. The Spanish scientific diaspora is an extensive network committed to cooperation and brain connection.

Keywords: science diplomacy, scientific diaspora, brain-connection, science advisory bodies, brain drain/gain

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INTRODUCTION: THE GLOBAL SCIENTIFIC DIASPORA

It is well-documented that in all countries there is a balance between the scientists that leave the country and the international researchers that the country takes in. This process has occurred as the result of transnational academic mobility since the albors of science. However, when this equilibrium is negatively balanced there could be a relevant loss of scientific talent for the country (Salgado, 2016; Cavallini et al., 2018). In this regard, in 1963 the Royal Society coined the term brain-drain to define the emigration of scientists, technologists, academics and many other high-level professional groups, to obtain better salaries, equipment or conditions (Royal Society, 1963). This fact resulted in an unprecedented social and political debate, which made the United Kingdom change its policies for investment, attraction, and retention of talent (Balmer et al., 2009).

The scientific diaspora has always existed and will always exist, although it reached its peak in many countries at the beginning of the twenty-first century, as developed countries wanted to incorporate foreign knowledge and talent generating wealth and an improved economic competitiveness. However, it was more recently, in 2011, when the Royal Society published the report "Knowledge, Networks and Nations: Global Scientific Collaboration in the twenty-first Century" (Royal Society, 2011) and defined the characteristics of the current global scientific diaspora. This study provided an overview of the global scientific landscape and showed the growing importance of research collaboration. The report concluded with five main recommendations that can be summed up in one: international science and collaborations must continue to be supported and promoted to address global challenges—a shift toward brain linkage or connection. Something that, 10 years later, still seems to be more fashionable than ever. Today science is understood—or should be understood—as a global phenomenon in which mobility of talent and international collaboration play a key role. In this regard, the report also highlights the fact that there are more than seven million researchers around the world who want to collaborate with the best professionals in their field to seek new knowledge and to make progress (Royal Society, 2011). Indeed, the so-called global scientific diaspora was the subject of study in the journal *Nature* in 2012 (Van Noorden, 2012). This study shows that, when researchers move abroad, they mainly have professional development in mind and to achieve this they seek the most suitable environments in terms of training, critical mass, and resources. Scientists, in their search for intellectual and scientific prosperity, move to countries with a consolidated R&D system and with solid foundations that offer them long-term guarantees. These systems are dynamic and flexible, with well-defined professional projection paths and great transverse mobility—across institutions, regions, fields of knowledge and sectors. Added to this is the fact that scientists are attracted to systems in which the research career is based on meritocracy, which guarantees scientific excellence and a powerful professional group made up of the best researchers in the host country. On the other hand, scientists also emigrate due to lack of opportunities in their countries of origin (Suresh, 2012; Cavallini et al., 2018). This exit is positive when individuals educated abroad are capable of reverting what they learned abroad to the country in which they began their educational development, or when the foreign "brains" come to nourish the gap left by those who moved out. This has been called brain circulation, and it is something that other countries know very well (Johnson and Regets, 1998; Kone and Ozden, 2017; Yu, 2021). In addition, encouraging brain connection between countries has proved to be useful for Science and multilateral collaborations between countries (Meyer and Brown, 1999; Gamlen, 2006; Balmer et al., 2009; Kone and Ozden, 2017; Yu, 2021).

CONTEXT: SPAIN'S PARTICULAR SCENARIO

The relevance of scientific mobility phenomena and brain-drain was early understood by governments in certain countries that established transnational mobility policies allowing them to attract talent and diversity. This was translated into economic prosperity thanks to a proper balance between the talent emigrated, brain-drain, and the talent attracted or retained, brain-gain, as it is the case of Sweden with its well-known and established programs from the Swedish Research Council (Vetenskaprådet, 2018). This ratio is an important diagnostic marker of any country's economic health, since the most developed countries invest a significant percentage of their GDP in science, research, development and innovation to maintain this balance. This effect can be seen with other examples, such as that of the Scandinavian countries, where both Sweden and Denmark invest over 3% of their GDP, a figure that falls short when compared to those of countries such as Israel and South Korea, which are close to 5% (OECD Data, 2000–2020). In other countries such as Spain, a modest 1.25% at the end of 2020, similar to what was achieved by the end of a domestic economic boom in mid 2006, according to the National Institute of Statistics (INE, 2020), translates into a slowdown of what should be the core of the country' machinery: research, development and innovation (R&D&i). Indeed, Spain has traditionally been a country with a very low investment of its GDP in R&D&i, having reached its maximum level of 1.36% in 2010, still far by more than one point from the world average, which is close to 2.5% (OECD Data, 2000–2020; INE, 2020).

After the 2008 Great Recession, Spain plunged into a major economic crisis. This worldwide economic crisis, which originated a year earlier in the United States, was mainly due to subprime mortgages that led to the bankruptcy of Lehman Brothers. This crisis strongly affected the economy of the European Union, whose states had accumulated huge amounts of debt, orchestrated under the pressure of Germany which was also tremendously hit by the crisis, but from which it has been recovered without digression (Szczepanski, 2019).

Nevertheless, in Spain, the crisis had an additional internal aspect, mainly due to an unprecedented real estate bubble, at the level of both the construction business and the financial system. The high unemployment level in the country led to a massive outflow, not only of immigrants who had come to work in construction during the previous years, but also of young people who were forced to leave (Royo, 2020), despite their being, most likely, the best educated generation in our history. This brain-drain forced many young people to emigrate to traditional "embracing" countries such as the US and the UK, but also to new destinations such as Sweden, Switzerland, Denmark, France, Germany and even Mexico, where opportunities for development and a stable future were greater (Van Noorden, 2012; Salgado, 2016). This emigration of labor reached all sectors and reduced assets in the Spanish Science and Technology system.

As already pointed out, one of the reasons for scientists to emigrate is the lack of opportunities in their countries of origin—something that happened with special emphasis in Spain. If we take a look at the situation in other countries, such as the United Kingdom, there is almost a balance between researchers who leave the country for destinations such as the US, Canada and Australia, mainly, and those received from these countries, mainly Italy and Germany. This is also the case in Germany, where the balance is even more obvious. In 2012 the percentage of researchers who left Germany was 23%, similar to the percentage of international researchers who chose this country as their destination according to data from the GlobSci survey (Van Noorden, 2012). Spain, in that year, showed a similar pattern to Germany's, but with a percentage three times lower and with an international immigration profile of countries where the language was close to Spanish, such as France and Italy, or exactly the same, in the case of Argentina (Van Noorden, 2012). The study published in *Nature* also highlights that the three countries chosen by Spanish scientists as the main destinations were, and still are, the US, the UK and Germany, followed by Japan, France, Australia, and the rest of the EU (Van Noorden, 2012; Salgado, 2016).

Today we still lack accurate, updated figures about emigration in the R&D sector. According to the OECD, in 2011 there were around 12,000 Spanish researchers abroad (OECD, 2013). But that number increased in subsequent years. In fact, according to 2015 data from the British Higher Education Statistics Agency, in British universities alone, there was a 40% increase in the total number of Spanish researchers compared to 2012 (HESA, 2022). Therefore, on the basis of the same assumption, we can say that the global number of Spanish researchers abroad reached around 20,000 in the following years, almost 0.1% of the total emigration, specialized in science, technology and research in general—which represents around 10% of the workers in the sector (OECD, 2013). These figures are still striking, and this is why the word "exodus" (or rather we should call it exile) is often mentioned in different forums, not only regarding thousands of young, and not so young, people who have left our country, in many cases taking their families with them and facing a rather uncertain future with slim chances of return (Ortega-Paíno and Oliver, 2021).

THE RISE OF SPAIN'S ORGANIZED SCIENTIFIC DIASPORA

The loss of critical mass in Spain, due to the aforementioned crisis and the fact that Spaniards started to improve their language skills in English mainly, is followed by another immediate consequence: an increased diaspora. A good example of this, after the 2008 crisis, is the birth of associations of scientists and researchers working in other countries. This associative

TABLE 1 | The 18 associations of Spanishs scientist and researchers abroad officially launched from 2012 to 2020.

Association name and acronym	Host country	Year of registry	Website
Sociedad de Científicos Españoles en Reino Unido (SRUK/CERU)	United Kingdom	2012	www.sruk.org.uk
Españoles Científicos en USA (ECUSA)	United States	2013	www.ecusa.es
Sociedad de Científicos Españoles en la República Federal de Alemania (CERFA)	Germany	2014	www.cerfa.de
Asociación de Científicos Españoles en Suecia (ACES)	Sweden	2014	www.aces-sffs.com
Científicos Españoles en Dinamarca (CED)	Denmark	2014	www.ced-sfd.org
Spanish Researchers in Australia-Pacifico (SRAP)	Australia	2015	www.srap-ieap.org
Asociación de Científicos Españoles en Japón (ACEJapon)	Japan	2016	www.acejapon.jp
Asociación de Investigadores Españoles en la República Italiana (ASIERI)	Italy	2016	www.asieriitalia.altervista.org
Spanish Research Society in Ireland (SRSI)	Ireland	2017	www.srsireland.org
Red de Científicos Españoles en México (RECEMX)	Mexico	2018	www.recemx.com.mx
Científicos Españoles en Bélgica (CEBE)	Belgium	2017	www.cebebelgica.es
Red de Investigadores China-España (RICE)	China	2017	www.ric-e.net
Asociación de Científicos Españoles en la Confederación Helvética (ACECH)	Switzerland	2018	www.acech.ch/
Sociedad de Investigadores Españoles en Francia (SIEF)	France	2018	www.siefrancia.com
Asociación de investigadores españoles en Noruega (IENO)	Norway	2018	www.sfnoieno.wordpress.com
Científicos Españoles en Países Bajos (CENL)	Holland	2019	www.cenetherlands.nl
Asociación de Científicos Españoles en Sudáfrica (ACE Sudáfrica)	Sudafrica	2019	acesudafrica.wordpress.com
Asociación de científicos e investigadores españoles en Emiratos Árabes Unidos (ACIEAU)	United Arab Emirates	2020	www.acieau.es

movement, born in the United Kingdom between 2011 and 2012, inspired other countries and as a result, in the following years, the Spanish scientific diaspora became organized (Catanzaro, 2012).

Since that date, 18 associations of Spanish scientists (plus 1 recently set up in Chile and 2 more in the process of constitution, in Canada and Brazil) have been born in five continents, which up to date represent more than 4,000 "brains" (**Table 1**). These grass-roots citizen associations are independent, non-profit, non-partisan, but not apolitical scientific societies—since one of their main purposes is to work on policies that may improve the situation of their origin country's R&D&I system. These organizations have been conceived and orchestrated by scientists eager to maintain ties with Spain, promoting multilateral relations and bringing the experiences of other countries closer together (Melchor, 2016; Oliver, 2016).

These grass-roots associations were set up with several objectives: to become an efficient network that connects Spanish researchers in the country of destination and supports newcomers; to disseminate science at all levels of society, actually raising awareness of the relevance of their progress and the importance of investing in them; to take science where it is least expected in its desire to disseminate, but also organize seminars and symposiums with the most prestigious Spanish researchers and introduce them in their destination countries; to dedicate efforts to build bridges of international collaboration between groups, associations and institutions bilaterally and multilaterally; to sign agreements with leading universities and research centers to encourage joint participation in European projects; to facilitate the exchange of researchers between countries and carry out the task of mentoring to advise those who are emigrating in their formative thinking (Melchor, 2016; Oliver, 2016).

In a clear work of Science diplomacy, this probably being the best of the consequences that the brain-drain has been able to revert to Spain, our assets abroad act as advisory bodies to Spanish public and private organizations, sharing the knowledge and experience of thousands of professionals from different fields of science or presenting reports, recommendations, and critical analyses with proposals for improvement (RAICEX News, 2021a). Many of these scientists have lived in multiple countries, have years of experience abroad, and are extremely knowledgeable about the work in R&D systems in some of the world's leading countries. For all these reasons, researchers and governments understood that maintaining good contact with the scientific diaspora—a brain-connection approach- could be highly beneficial since they represent an asset for Science Diplomacy and a way of recovering lost talent (Gamlen, 2006; Elorza Moreno et al., 2017; Kone and Ozden, 2017).

DETAILS OF THE CASE STUDY: RAICEX, THE NETWORK OF ASSOCIATIONS OF SPANISH SCIENTISTS AND RESEARCHERS ABROAD

In July 2018, the representatives of 15 of these associations of Spanish scientists and researchers abroad—the ones existing at that time—joined efforts in a unique voice and founded the so called network of associations RAICEX (Red de Asociaciones de Investigadores y Científicos Españoles en el Exterior) (SINC, 2018). RAICEX is an independent, non-profit organization made up of 18 associations registered in different countries (**Table 1**), which was born in response to the growing need to unite and represent the community of Spanish scientists and researchers abroad, under a common framework. Their general interest is to transmit and share the skills and knowledge acquired in a global scientific context and multilateral collaboration (**Figures 1**, **2**). RAICEX's mission is to promote the exchange of experiences and knowledge between Spanish researchers and scientists abroad and all the stakeholders of the SECTI, serving as an advisory body, channeling information and catalyzing international relations multi-directionality in scientific matters, thus contributing to the progress of science. The global objective of RAICEX is to generate a single voice that, respecting the independence of each association, encompasses Spanish scientists and researchers abroad in a common forum, pursuing the following objectives: (1) In the training of Researchers and Scientist: to support researchers and scientists in terms of mobility and professional development, providing training, information and guidance, as well as facilitating contact with all associations; (2) In communication with Society: to disseminate, give prestige and visibility to the value of Science and the work of researchers and scientists, while promoting the communication of scientific and technological advances in all areas of society; (3) In the internationalization of the Scientific Community: to favor international relations and cooperation between researchers/scientists, public and private organizations and bodies, from a global perspective in matters of research, science and technology, thus promoting networking; (4) In advising SECTI: to share the experience and knowledge acquired in the different research and science systems abroad to advise, provide feedback and contribute to the progress of SECTI as a whole (**Figure 1**) (RAICEX, 2018).

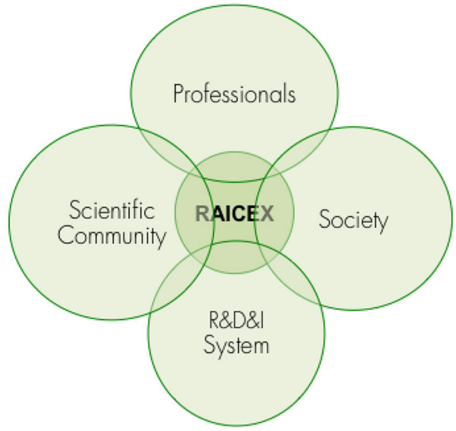

FIGURE 1 | The impact of RAICEX's activities and objectives.

RAICEX is made up of its main body, the Assembly of Members (AoM), in which the 18 countries (**Figure 2**) are

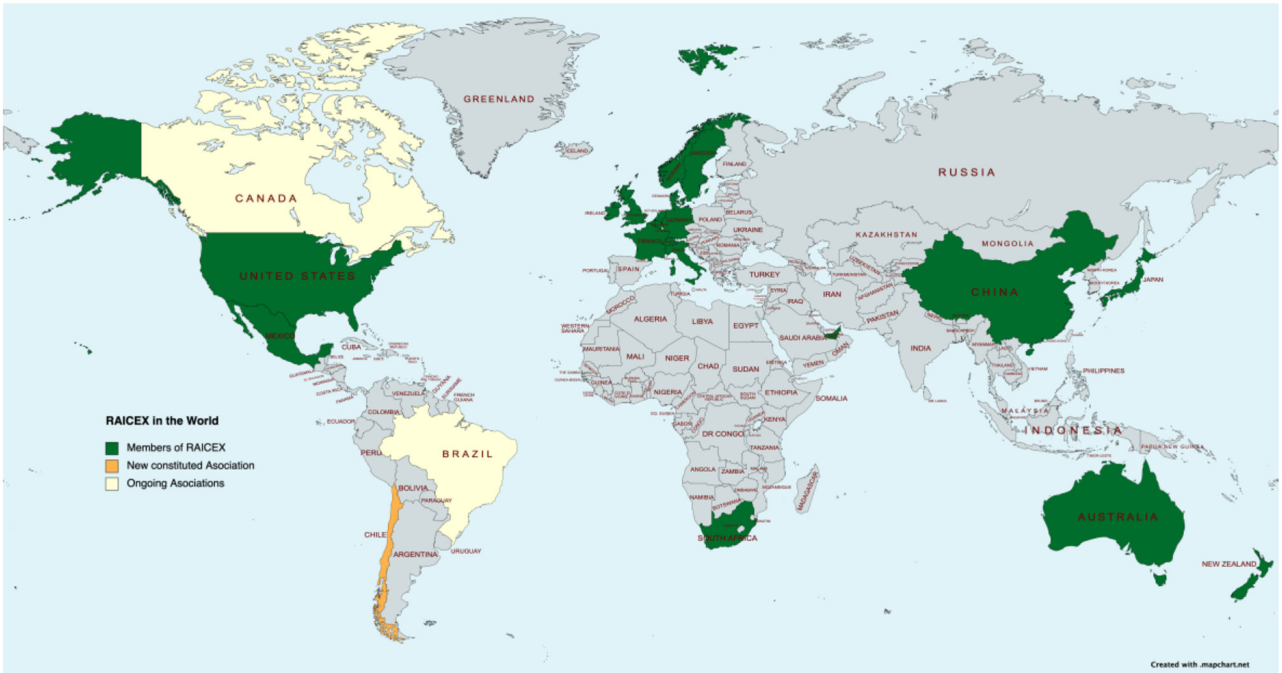

FIGURE 2 | The world-wide presence of RAICEX members. Green color represents active members; Orange color represents new constituted associations yet to sign the incorporation agreement; Yellow color represents incoming new association. The figure represents data from 2012 to 2022.

represented by their legal body, usually their presidents. The AoM elects their Managing Committee. This Committee is the decision-making body of the network and is also in charge of electing the Secretary General (SG) and the External Advisory Board (EAB). The Managing Committee also decides the *ad-hoc* commissions needed for the proper functioning of the network. Currently, RAICEX has 3 commissions working on science policies and diplomacy, gender equality and communication. The Secretary General, represented by a managing member from any of the associations who has returned back to Spain, performs the role of Public Affairs Officer of the network and represents the network in Spain wherever required (RAICEX, 2018). This role has allowed direct interaction with the main bodies or stakeholders of the Spanish scientific landscape such as the Ministry of Science, Technology and Innovation, the Spanish Agency for International Development Cooperation (AECID), the Spanish Foundation for Science and Technology (FECYT) and many other actors both in the public and the private sector.

DISCUSSION

Since RAICEX was set up, the network, as well as its activities, have increased in number and impact. The participation of RAICEX as an advisory body for science policy and diplomacy has been growing and, RAICEX has been involved in the Amendment to the Science Act 14/2011 (RAICEX News, 2022a), a public call where members of the SECTI can submit comments and recommendations to improve the law. In line with this, RAICEX was previously invited to present their views on the new Science Act and the National Pact for Science and Technology in front of the Science committee of the Spanish Congress of Deputies (RAICEX News, 2021b). At present, RAICEX is (1) collaborating with the main public and private stakeholders, such as the Ministry of Science, Technology and Innovation, the Ministry of Foreign Affairs, the Ministry of Migrations as well as Instituto Cervantes, the Royal Academy of Sciences, the Spanish Association for Biotechnology (ASEBIO), Farmaindustria, Fenin, among others, to draw up and elaborate policies for attraction and retention of domestic as well as international talent (data extracted from RAICEX website). This will be reflected in the ATRAE (Attraction and retention of talent to Spain) report, an initiative of RAICEX. This report is based on ten main commandments and developed by the scientific policy and diplomacy commission (RAICEX Science Policy Talent Attraction committee, 2019). The extended version of this report is expected to be publicly presented in the autumn of 2022; (2) giving visibility to their diaspora by collaborating with the Spanish Broadcasting Corporation (RNE) and performing weekly interviews with their members abroad, as well as in other radio programmes and newspapers; (3) participating in mentoring programmes such as Researchers Beyond Academia (REBECA), a mentoring programme for researchers who want to explore careers beyond the academic pathway organized by EURAXESS Spain (FECYT, 2021); (4) working on gender inequality matters and collaborating with other associations and universities to study and narrow the existing gender gap in science and technology. This commission has developed videos to show this gap and raise awareness within society (RAICEX Research Gender committee, 2022); (5) organizing scientific meetings, such as the series Bridging European Science within the Nordic Countries Associations, among others; and last but not least, (6) building bridges in cancer research through collaborations with a founding agent, CRIS cancer, by providing grants to Spanish researchers who later pend a couple of months back in Spain, therefore, favoring talent attraction (RAICEX News, 2022b). These examples represent only the most relevant and recent achievements that can be extracted from the RAICEX website.

In recent years, many voices from groups of researchers and scientists have demanded changes within the SECTI. Many of these voices, and those gathered abroad in associations of researchers and scientists in particular, came together in 2018, as mentioned above, in a single voice channeled by RAICEX. From this group, as well as from the same national researchers and other organizations, concerns have been expressed, proposals have been presented, mobilisations and demonstrations have been organized under the slogan *#SinCienciaNoHayFuturo (No Science, No Future)*, to position Spain in the international frontline of Science and Innovation. A task that, without being pessimistic, seems quite complicated if we take into account that, traditionally, science has never been the main character in the play (Segurola, 2014).

Echoing these voices, in July 2020 and after more than a decade of continuous cuts, the Government, in an attempt to revive our R&D&i system as if it was an intensive care unit, presented in Moncloa the Shock Plan for Science, with short-term measures that would serve as a hinge for the future "Investment and Reform Plan for the Recovery of the Economy." The Plan encompasses three basic axes: investment in research and health; the transformation of the science system and the attraction and retention of talent and the promotion of business and industrial R&D&i in science (Moncloa, 2020). This Shock Plan was followed by proposals such as the National Pact for Science and Innovation, insistently demanded by many scientific groups, and which has been joined by 86 entities, included RAICEX (RAICEX News, 2020). The objectives of this long-awaited Pact are focused on Resources, the System and People. There is no doubt that these three ingredients are essential in the master recipe for European investment under the Recovery, Transformation and Resilience Plan, which the Government had expected as if it was manna.

As of today, the actors involved in Science and Innovation are looking forward to the development of the draft bill proposal that has already been presented to the Congress of Deputies and on which an *ad-hoc* subcommittee is already working. This preliminary project is still supported by three basic pillars: the scientific career, transfer to society and governance. Three pillars that, as a master formula, include the need to increase the number of R&D&i assets, to attract emigrated talent, to increase public-private collaboration and, of course, to maintain everything orchestrated under a governance that facilitates the coordination of this cast in science (Ministerio de Ciencia e Innovacion, 2022).

When looking overseas, RAICEX (and its members) is not the only organized scientific diaspora in the world. In fact, students, investigators and graduated Portuguese workers of all areas in science are represented by the Portuguese Association of Researchers and Students in the United Kingdom (PARSUK) a network that promotes the integration, collaboration, and development of their members (PARSUK, 2008). Similar to this, Polish research diaspora is organized under the umbrella of Polonium Foundation, an independent non-profit aiming at turning Polish brain drain into brain circulation (Polonium Foundation, 2016). As a matter of fact, since 2016 EURAXESS organize an annual meeting of European scientific diasporas in North America form which it publish a report with views and analysis from the speakers that can be useful for governments (EURAXESS, 2016). Also recently analyzed in this issue, the diaspora organizations from Latin America and the Caribbean has been found to be a tool to engage with governmental and non-state actors and are active science diplomacy stakeholders promoting the scientific developments of their country or their researchers, as well as enabling access to research resources creating alliances for scientific, institutional, and academic collaborations (Figueroa et al., 2022). Nevertheless, there are some aspects that make RAICEX unique if compare to other diasporas: (a) it is a bottom up initiative created by the own scientists to collaborate and connect with Spanish public and private scientific institutions; (b) it is a big network of networks, since it represents a big number of associations which are independent themself allowing them to perform their own activities; (c) it is present in more than eighteen countries within five continents while having a general secretary head quarter in Spain which boost connections with institutions and organizations in the country; (d) it serves as an umbrella to boost the power of representation of its association members beyond Spanish institutions while the associations play an important role connecting the network world-wide.

As RAICEX grows—the association in Chile has been recently set up and others, in Brazil and Canada, are on their way—there are new goals to achieve in providing the network with a proper, effective structure. These goals could be summarized in: (1) building the network of RAICEX ambassadors to give support geographically to the Secretary General by increasing the participation of the network in as many activities and meetings with its stakeholders as possible in all Autonomous Regions in Spain; (2) creating an *ad-hoc* commission for fundraising; (3) acting as an advisory board and channel to as many stakeholders as possible in developing policies that could help those scientists and researchers wishing to return to Spain; and (4) interacting and advising our embassies abroad in science and technology-related issues and topics for solving global challenges that could arise, as has been the case with the Covid-19 pandemic.

CONCLUSIONS

The need for organizing the diaspora has now been established. The Spanish Scientific Diaspora, set up in 18 different countries, with 4 more under way on-going, and acting under the umbrella of RAICEX, is a clear example of success that can help to become an advisory body to governments and institutions, by advising newcomers and carrying out science dissemination. The Spanish Scientific Diaspora represented by RAICEX is an extensive network committed to cooperation and brain connection. Being connected and listening to demands from scientists, not only inside but outside the country, can contribute to providing us with a more attractive system capable of attracting and retaining domestic and international talent.

AUTHOR CONTRIBUTIONS

EO-P and EO equally contributed to interpreting this case study. Both authors contributed to the article and approved the submitted version.

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Conflict of Interest: EO-P is the current General Secretary of RAICEX and ambassador of ACES in Spain. EO is the former General Secretary of RAICEX and ambassador of SRUK in Spain.

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Biodiversity Research in Central America: A Regional Comparison in Scientific Production Using Bibliometrics and Democracy Indicators

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Central America science production on biodiversity topics is important in planning future adaptive and conservation policies in a climate-related risk region that is considered a biodiversity hotspot but has the lowest Human Development Index of Latin America. Science production on biodiversity is related to geo-referenced species occurrence records, but the accessibility depends on political frameworks and science funding. This paper aims at foregrounding how the democratic shifts throughout the years have had an impact on science production on biodiversity research, and species records. For this exploration we developed a novel systematic scientometric analysis of science production on biodiversity topics, we used Bio-Dem (open-source software of biodiversity records and socio-political variables) and briefly analyzed the history—from 1980 to 2020—of Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama. With a data set of 16,304 documents, our analysis shows the significant discrepancies between the low science production of Central American Northern countries (Guatemala, El Salvador, Honduras, and Nicaragua), the prolific production from the Southern (Costa Rica and Panama), and how this relates to democratic stability. Scientific production tends to be more abundant when democratic conditions are guaranteed. The state capture phenomenon and colonial-rooted interactions worldwide have an effect on the conditions under which science is being produced in Central America. Democracy, science production, funding, and conservation are core elements that go hand in hand, and that need to be nourished in a region that struggles with the protection of life and extractive activities in a climate change scenario.

Keywords: science mapping, biological diversity, species records, political corruption, Latin America, GBIF, climate change, state capture

INTRODUCTION

The Central American region has nuances in the development of its young democracies. Historical events such as colonial invasions, civil wars and democratic transitions have shaped the current state of governance, public policies, land use, natural and economical resource administration. On a global scale, Guatemala, El Salvador, Honduras, Nicaragua, and Panama ranked in the lowest positions of the Human Development Index for Latin America, on the contrary to Costa Rica which ranked amongst the top five (United Nations Development Programme, 2020). The investment in biodiversity research, embedded in academic and political efforts, also expresses these democratic and development frames (Barlow et al., 2018; Legagneux et al., 2018; Zizka et al., 2021). Science in Central America has had to navigate these contexts to generate funding opportunities to provide more data for public policy decision-making processes.

Central America harbors 5–12% of the planet's biodiversity, it is known as a hyperdiversity hotspot in the Neotropical region. This area is considered, for instance, one of the top five most diverse regions for vascular plants. It is a key area for understanding ecological, evolutionary and human demographic processes linked to the Tropical Rainforest species, because it connects North and South America (Barthlott et al., 2007; Kohlman et al., 2010; Meyer, N. F. et al., 2015; Eiserhardt et al., 2017; Barlow et al., 2018; Cano et al., 2022). The dynamic landscape of Central America had a direct impact on the diversification and colonization of biota in the isthmus, thus creating new niches. Despite the region's potential for investigation, little attention has been given in comparison to other Neotropical regions. Maybe, we asked ourselves, this lack of research has a reason involving democratic instability.

Tracking species records and science production on biodiversity topics is a way to estimate how much a country invests in understanding its natural resources. Central American countries have the lowest science funding of all Latin America, fostering a brain drain phenomenon (Bonilla, 2018; Bonilla and Serafim, 2021). The knowledge gaps compromise our ability to describe existing biodiversity and make accurate predictions that could support decisions in regards to climate change scenarios. This is observed in the great difference between the countries that have state scientific support, which are also the ones presenting better democratic indicators, versus those who don't and the number of species records they present (Zizka et al., 2021).

Species occurrence data is not updated in certain regions and habitats near conflict areas. Biodiversity inventories are more complete and comprehensive near locations where access, infrastructure and security is granted (Hortal et al., 2015; Meyer, C. et al., 2015; Daru et al., 2018). There are also historical patterns and colonization processes that modified the inventorying of biodiversity and its research, where endangered species and conservation projects could be affected (Eichhorn et al., 2020; Rydén et al., 2020). The geographic distribution of species and their link to human activities is essential in understanding commodity production, furthermore having a direct association with agriculture, health and social dynamics (Clement et al., 2004). Considering that Central American core commodities are tied with agrobusiness, biodiversity research is key in the construction of guidelines for regional development.

This study explores three elements of the Central American democracies—freedom of expression, political corruption, and polyarchy—in light of weak democratic transitions which led to a state capture phenomenon. Hellman and Kaufmann (2001) define state capture as "the efforts of firms to shape the laws, policies, and regulations of the state to their advantage by providing illicit private gains to public officials." This phenomenon, also referred to as democracy privatization, names the influence that individuals, organizations or companies have upon the institutions and state policies in order to push for their own interests and against the population's wellbeing. The capture operates through mechanisms such as fiscal evasion, bribes to push for tailored laws, social leaders' criminalization, lobbying, financing political campaigns, revolving doors, investment in media, judicial capture, and violation of social, cultural and environmental rights. Therefore, state capture as a form of systemic corruption weakens democracy and erodes the possibility of research development via solid academic public institutions.

Biased data in species records or science production, or the lack of it, could limit the use of biodiversity information for legislation, conservation, and management (Rydén et al., 2020). In hyperdiverse countries like the ones comprising the Central American area, this lack of informed regulations and the laxity with which transnational extractive projects are treated appear to be elements that allow continuous unregulated resource exploitation. If we follow the logic of the state capture phenomenon, the lack of scientific production regarding biodiversity could account for economic interests that would be affected by environmental protection measures. These contexts are not aligned with the worldwide call for global priorities, which includes generating an effective information basis of biodiversity distributions for safeguarding biodiversity and ecosystem services (Meyer, C. et al., 2015).

When comparing science production on biodiversity topics in Central America, there is a noticeable gap in the total amount of peer-reviewed scholarly works, patent development and work citations from the Northern countries (Guatemala, El Salvador, Honduras and Nicaragua) versus those from the South (Costa Rica and Panama). Costa Rica and Panama produce almost five times more scholarly works than their neighbors, being carried mainly by domestic researchers and institutions. On the other hand, the scholarly production from the rest of the region is executed mostly by international institutions whose first authors are commonly foreign researchers. The amount of georeferenced species occurrence records in natural collections, herbaria, and biological databases follows the same production tendency.

Over the last decades, this territory and its populations have been deeply affected by many tropical storms, hurricanes and other natural phenomena that evidentiate the region's vulnerability to climate change (Magrin et al., 2014; Hagen et al., 2022). This has been partially due to the lack of proper legislation that addresses forest coverage, biodiversity conservation, infrastructure and territorial ordering. How the state apparatus has been historically shaped and the way it operates through its judicial, executive and legislative branches, has a direct impact on what happens to the populations and species that inhabit these territories.

There is a historical and political explanation for these regional discrepancies, which we will attempt to unravel throughout the article using a bibliometric analysis and Bio-Dem –open-source software that compares species records and democratic variables per country– (Zizka et al., 2021). This paper aims at presenting a brief historical analysis from 1980 to 2020 of Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama[1], to foreground how the democratic shifts throughout the years have had an impact on scientific mobility, biodiversity research, and species conservation records. Civil wars, coup d'etats, revolutions, dictatorships, migration waves, and international interventions are all events that have molded these countries' legislative frame and, therefore, their biodiversity conservation guidelines and science production.

METHODS

To understand the connections between biodiversity research production and the political framework of Central America, we opted for two different strategies. The first one was to use Bibliometrix to map scientific production through publications dealing with biodiversity; and the second one was using the Bio-Dem tool to explore how the number of species records per country can be related to three democratic variables: freedom of expression, political corruption, and polyarchy. Consequently, we examined how the historical shifts of such variables by country can explain the phenomena of state capture in the region and its impact on science development.

The historical milestones that define the traits of democracies in Guatemala, El Salvador, Honduras, Nicaragua, Costa Rica, and Panama were selected by means of a bibliographical revision centered in institutional documents, legislative proposals, newspaper articles, history books and peer-reviewed historical papers. Special attention was given to electoral processes, belligerent national conflicts, migratory waves, and natural phenomena, events that could account for the prominent fluctuations in the number of publications dealing with biodiversity topics per country, the differentiation of species records per country, and the links between local and international research institutions. It is important to mention that two of this paper authors are Central American with international graduate degrees, which allows for an insider's perspective on the regional history and the brain drain tendency.

[1]This analysis did not include Belize on the account that it is a parliamentary constitutional monarchy following the British model after gaining independence in 1981, and not a presidential representative democratic republic, like the rest of the Central American countries which in the 80s were experiencing convulsion due to civil wars and dictatorships. There is also a cultural difference between Belize and the rest of the region's countries in terms of the language.

First Strategy: Data Collection and Bibliometric Analysis

To explore the amount of research on biodiversity being carried in Central America, we compared the scientific production on biodiversity subjects from 1980 to 2020 for each country, assessed through a science mapping analysis using Bibliometrix (open-source R-tool package) (Aria and Cuccurullo, 2017) and VOSviewer (1.6.18) (van Eck and Waltman, 2010). The bibliometric analysis strengthened the theoretical argument linking the three selected democracy variables, as proxies to the state capture phenomenon, and biodiversity research advances.

The data set was built through the Web of Science (WoS) indexing database accessed on January 31st, 2022. We opted for using WoS for its older trajectory in comparison to new–comer databases like Scopus. Given that our historical approach dealt with democratic shifts from 1980 to 2020, WoS was the best choice. There are multiple studies comparing these two databases, for our case, WoS presented more entries in environmental and biological sciences (Zhu and Liu, 2020). We built a search query using terms in titles, abstracts, and topics related to "biodiversity." The search was refined by using only peer review publications in English, conference communications were excluded.

The next Boolean search query was used: TI = (Country) OR AB = (Country) OR TS = (Country) AND [TS = (biodiversity OR "biological diversity" OR Specie* OR "species diversity" OR "species richness" OR "genetic diversity" OR ecosystem* OR "invasive species" OR "endangered species" OR "conservation biology" OR "biodiversity conservation" OR biogeography OR "new species" OR taxonomy OR phylogeny OR "landscape ecology" OR "landscape")] Timespan = 1980–2020. In WoS, "TI" = title, "AB" = abstract and "TS" = topic, relates to keywords, abstract, title, and keywords in this field. Documents in the fields of medicine, anthropology, archeology, business, economics, and social sciences were excluded. We validate our search queries for each country by reviewing the 50 most relevant entries and confirm that they suited the subject of biodiversity.

For the bibliometric analysis, the retrieved data was classified in four decades from 1980 to 2020 for each Central American country. It included the number of publications per country,[2] top publishing country vs. local country number of publications, the top three publishing institutions, and the top five publishing authors (**Table 1**). All the authors appearing in the publications were counted. The top five authors were mapped in order to foreground their origin and scientific career, giving more attention to the affiliations for understanding the brain gain/drain process. The non-Central American top authors with a Central American institution affiliation were considered as part of the brain gain process in the region. The latter phenomenon, however, presents a much lower occurrence. The dataset used for the analysis is available in the FigShare

[2]The variable "country" for an entry is where the corresponding author(s) have their main institutional affiliation.

TABLE 1 | Bibliometric analysis of scientific production in biodiversity topics per decade from 1980 to 2020 in Central America.

Decade	Country	Number of publications	Top publishing country vs. local*	Top publishing institutions	Top publishing authors**
1980–1989	Guatemala	206	USA (46), GT (1)	(1) University of Wisconsin-Madison (2) North Carolina State University (3) University of Florida	David B. Wake Robert F. Martin Jack C. Schuster **(+)** David W. Greenfield Jonathan A. Campbell
	El Salvador	50	USA (10), SV (1)	(1) University of Costa Rica (2) University of Colorado (3) Shimane University	Jimmie C. Skinner Peggy S. Stanfill William E. Collins Hugo Hidalgo **(CA)** John S. Garth
	Honduras	108	USA (21), HN (3)	(1) York University (2) University of Florida (3) University of Costa Rica	Larry David Wilson James R. McCranie Martin Kellman John Hudson **(+)** Kenneth L Williams
	Nicaragua	76	USA (19), NI (1)	(1) Texas Tech University (2) University of Montana (3) University of California Berkeley	Egbert W. Pfeiffer Alison G. Power Curtis W. Sabrosky James E. Henrich Grady L. Webster
	Costa Rica	584	USA (142), CR (43)	(1) University of Costa Rica (2) University of Florida (3) University of California Berkeley	Daniel H. Janzen **(+)** Allen M. Young **(+)** Steven F. Oberbauer **(+)** Boyd R. Strain Gordon W. Frankie **(+)**
	Panama	634	USA (175), PN (42)	(1) Smithsonian Institute (2) University of Illinois (3) University of California Los Angeles	Henk Wolda **(+)** Carol K Augspurger **(+)** Russell Greenberg **(+)** David W. Roubik **(+)** Howard A Christensen (+)
1990–1999	Guatemala	324	USA (52), GT (5)	(1) National Autonomous University of Mexico (2) United States Department of Agriculture (3) University of Texas	Jonathan A. Campbell Gerald A. Islebe Eric N. Smith Jack C. Schuster **(+)** David B. Wake
	El Salvador	51	USA (10), SV (1)	(1) University of Colorado (2) National Autonomous University of Mexico (3) Louisiana State University	James R. McCranie Larry David Wilson W. E. Clark Cuauhtemoc Deloya A. Gomez-Sal **(CA)**
	Honduras	210	USA (36), HN (2)	(1) University of Florida (2) University of Connecticut (3) North Carolina State University	James R. McCranie Larry David Wilson David B. Wake David Lentz Janet W. Reid
	Nicaragua	151	USA (21), NI (2)	(1) University of Michigan (2) University of Maryland (3) Smithsonian Institute	Douglas H. Boucher John Vandermeer Amy Pool Francisco Collantes Ivette Perfecto
	Costa Rica	1137	USA (267), CR (67)	(1) University of Costa Rica (2) University of Florida (3) University of Miami	David B. Clark **(+)** Robin L. Chazdon Robert Lucking Deborah Clark **(+)** Manuel R. Guariguata
	Panama	831	USA (235), PN (125)	(1) Smithsonian Institute (2) University of Panama (3) Princeton University	Stephen P. Hubbell **(+)** Richard Condit **(+)** Robin B. Foster **(+)** Eldredge Bermingham **(+)** Klaus Winter **(+)**
2000–2009	Guatemala	655	USA (190), GT (19)	(1) National Autonomous University of Mexico (2) Autonomous University of San Carlos of Guatemala (3) University of Florida	Alejandro Estrada Enio B. Cano **(CA)** Jonathan A. Campbell Swen C. Renner David F. Whitacre
	El Salvador	191	USA (19), SV (6)	(1) University of Kansas (2) National Autonomous University of Mexico (3) University of El Salvador	Oliver Komar **(+)** V. Ernesto Méndez **(CA)** Bert Kohlmann **(+)** Alan S. Robinson David d Dame
	Honduras	413	USA (123), HN (4)	(1) University of Florida (2) Louisiana State University (3) National Autonomous University of Mexico	James R. McCranie Larry David Wilson Marco A. Zambrano David L. Anderson Josiah H. Townsend **(+)**
	Nicaragua	471	USA (109), NI (26)	(1) National Autonomous University of Mexico (2) Tropical Agricultural Research and Higher Education Center of Costa Rica (3) Central American University	Axel Meyer Jeffrey K. McCrary **(+)** Per Christer Oden Benigno González-Rivas **(CA)** Ivette Perfecto

(Continued)

TABLE 1 | Continued

Decade	Country	Number of publications	Top publishing country vs. local*	Top publishing institutions	Top publishing authors**
	Costa Rica	2,820	USA (891), CR (354)	(1) University of Costa Rica (2) National Autonomous University of Mexico (3) National Institute of Biodiversity of Costa Rica	Daniel R. Brooks Daniel H. Janzen **(+)** Jorge Cortés **(CA)** Florencia Montagnini **(+)** David B. Clark **(+)**
	Panama	1,982	USA (730), PN (347)	(1) Smithsonian Institute (2) National Autonomous University of Mexico (3) University of Panama	Eldredge Berminghan **(+)** Hector M. Guzman **(CA)** Elisabeth K. V. Kalko **(+)** Richard Condit **(+)** S. Joseph Wright **(+)**
2010–2020	Guatemala	1,233	USA (366), GT (145)	(1) National Autonomous University of Mexico (1) Autonomous University of San Carlos of Guatemala (3) University of the Valley of Guatemala	Armando Cáceres **(CA)** Antje Schwalb Antonio Santos-Silva Liseth Pérez **(CA)** Danilo Alvarez **(CA)**
	El Salvador	372	USA (83), SV (43)	(1) University of El Salvador (2) National Autonomous University of Mexico (3) University of Costa Rica	Michael J. Liles Enrique Barraza **(CA)** Jeffrey A. Seminoff José D. Pablo-Cea **(CA)** Juan J. Morrone
	Honduras	862	USA (274), HN (70)	(1) National Autonomous University of Honduras (2) National Autonomous University of Mexico (3) University of Costa Rica	Merlijn Jocque James R. McCranie Joslah H. Townsend **(+)** Gustavo Fontecha **(CA)** Manfredo A. Turcios-Casco **(CA)**
	Nicaragua	972	USA (238), NI (77)	(1) National Autonomous University of Mexico (2) University of Konstanz (3) University of Costa Rica	Axel Meyer Kathryn R. Elmer Eva Harris Gonzalo Machado-Schiaffino Julián Torres-Dowdall
	Costa Rica	5,702	USA (1461), CR (1,120)	(1) University of Costa Rica (2) National Autonomous University of Mexico (3) Costa Rica Institute of Technology	M. Alex Smith **(+)** Winnie Hallwachs **(+)** D. Monty Wood **(+)** Daniel H Janzen **(+)** A. J. Fleming **(+)**
	Panama	3,619	USA (1266), PN (892)	(1) Smithsonian Institute (2) University of Panama (3) University of Costa Rica	S Joseph Wright **(+)** Benjamin L. Turner **(+)** Meike Piepenbring **(+)** Stephen P. Hubbell **(+)** Azael Saldana **(CA)**

**Including the number of publications per country.*
***(+) Authors with local affiliation; (CA) Authors born in Central America.*

repository—link in the **Supplementary Materials** section of the article.

The global data set (1980–2020 for all countries) consisting of 16,304 entries was also exported to the program VOSviewer (1.6.18) to create network visualization maps for the most influential countries, institutions, sources (journals), and terms in the Central American biodiversity science production. The strength of every node and its associations with the other elements in the network was presented as Total Link Strength (TLS) which is given in VOSviewer consequently by mapping research activity of the selected data set. The TLS is proportional to the extent of a specific node and its relationship with the other nodes, where a higher TLS value indicates greater collaboration, number of occurrences, and influence in the network. The threshold used for every map is explained in figures descriptions (**Figures 2**, **3**; **Supplementary Figures S1, S2**).

Second Strategy: Exploring Species Records Data and Socio-Political Variables Through Bio-Dem

In order to infer the amount of research on biodiversity being carried in Central America and how it is linked to the democratic environment of the region, we opted for using Bio-Dem (open-source software, www.bio-dem.surge.sh). This tool allowed us to explore the relationship between Central American species occurrence records from the Global Biodiversity Information Facility (GBIF) (www.gbif.org) and the region's political framework from the Varieties of Democracy (V-Dem) database (www.v-dem.net) from 1960 to 2020 (Coppedge, 2020; Zizka et al., 2021). Geo-referenced species occurrence records deposited in GBIF have become crucial for biodiversity research and data modeling (Feldman et al., 2021), while V-Dem is the world's largest database dedicated to the collection and conceptualization of democracy data (Coppedge, 2020).

The availability of species records is linked to geographic accessibility, local investment in research, and political contexts (Meyer, C. et al., 2015; Daru et al., 2018; Eichhorn et al., 2020; Rydén et al., 2020). Therefore, the Bio-Dem software accesses the species record per year by country and allows for the user to relate them to 13 socio-political variables, which were postulated for having an impact on species occurrence record availability (Zizka et al., 2021).

We analyzed species record occurrence data and its possible links to political environments for each Central American country (**Figure 1**). The three socio-political variables that were considered for our analysis are (1) Freedom of expression, (2) Political corruption, and (3) Polyarchy[3] (electoral democracy). Exploring these three elements of the Central American democracies will shed light on weak democratic transitions leading to a state capture phenomenon. There is a political and historical explanation for the gaps in species records in Central America which we will attempt to explain throughout this article

WHEN SCIENCE PRODUCTION MEETS DEMOCRACY (OR THE LACK OF IT)

Central America's democratic transition began in the 1980s with the *Esquipulas Agreement* (1986 and 1987), which sought to advance peaceful resolution of the regional conflicts and to promote economic and political cooperation between the isthmus countries (Sistema de Integración Centroamericana, 2022). This took place in the frame of the end of the Cold War and the fall of the Berlin wall in 1989. The ideological and geopolitical tensions embedded in the communism-capitalism debate were deeply felt in Central America. Therefore, when it started to seemingly decrease its intensity, it impacted the region's political forces configuration, which enhanced the possibilities of transitioning to what, in appearance, would look like a democratic era. However, as shown in **Figure 1**, the democracy indicators of the last decades highlight the political instability which has affected the chances of establishing strong research spaces in Central America, especially in those societies with a history of warfare, violence, and unstable electoral mechanisms. These conflicts were more acute in the region's Northern countries.

The internal conflict in Guatemala (1960–1996); the civil war in El Salvador (1979–1992); the overthrowing of the Somoza dynastic dictatorship in Nicaragua (1933–1979) and its subsequent contra revolutionary movement (1980–1991); Honduras having its first democratic elections in 1981 since 1971; and Panama undergoing the Noriega dictatorship (1981–1989), determined the last few decades of the twentieth century for the region and framed the chances of rigorous scientific production initiatives. While in 1989 Costa Rica created its local biodiversity think tank *InBio* (*Instituto Nacional de Biodiversidad*) in El Salvador eight Central America University (UCA) workers were assassinated by the regime, and Panama was having its first elections under US tutelage after the dictatorship (**Figure 1**). This is also reflected in the amount of science production and species records in the region. Political instability, apart from driving away investment opportunities, has obstructed inter-institutional science collaboration processes.

Renowned academics, thinkers, and social leaders were assassinated or disappeared during the guerilla war in El Salvador and Guatemala, internal conflicts that were supported by the US Government under the argument of the communist threats (Handy, 1984; Romano, 2012). These losses took a toll on the scientific population and emergent initiatives that would promote investments in research institutions that could guide data-based political and economic decisions. History itself was being contested by the powers involved in the decades-long conflicts in these countries, which impacted science production in the 1980s and 1990s, as shown in **Table 1**. Only after 2000, local institutions have had an influence on the research being carried on biodiversity topics in the region's Northern countries, which could be a byproduct of the democratic transition and how it enabled new funding influxes.

The democratic transition was supposed to reshape the State apparatus, integrating different sector interests: economic elites, high military stakeholders, big land-owners, and social minorities (laborers, women, indigenous, and Afro-Latin Central American populations). It would promote the redistribution of power quotas and the prioritization of resources investments. However, as expected after years of conflict and a history of colonial-cut state institutions, this process was rather a re-branding of the same former policies, leading to a deepening of structural inequalities with the entrance of neoliberal global economic policies promoted by Western countries. Said policies set the ground for the development of the state capture phenomenon worldwide, emerging strongly in the weak Central American democracies. "Civil war raged in Central America throughout the 1970s and 1980s and even into 1990s. It led to the deaths of at least 300,000 people, the vast majority of whom were killed by the military and/or right-wing hit squads. War produced between 1.8 and 2.8 m refugees. War also devastated the economies of El Salvador, Guatemala, and Nicaragua" (Lehoucq, 2014, p. 144). Intellectual exiles were amongst the population whom, to protect their lives, sought asylum as refugees elsewhere. Thus, becoming part of one the most significant diaspora of Central American thinkers of the last century.

The Washington Consensus in the 1990s, deemed as a neoliberalism starting point, promoted the so-called modernization of the State. These policy guidelines pushed for more market participation in social and economic matters (liberalization) resulting in the privatization of national services (Hernández Mack, 2010), and on a more pronounced shift toward extractivist concessions (mining, monocropping, irregular logging, hydroelectric dams). Such concessions had the tendency to operate through state capture mechanisms such as fiscal evasion, bribes and political lobbying, financing political campaigns, judicial capture and violation of labor, cultural and environmental rights. The latter led to evictions, repression, and the acute affectation of the region's ecosystems and biodiversity. The new international guidelines became requirements to apply for loans and funding from the International Monetary Fund (FMI) and the World Bank. This economic context along

[3] Following Zizka et al. (2021), polyarchy is understood as "to what degree does a regime select its executive and legislative through popular elections, whether these elections are free and fair, and how widespread the right to vote is" (p. 2718).

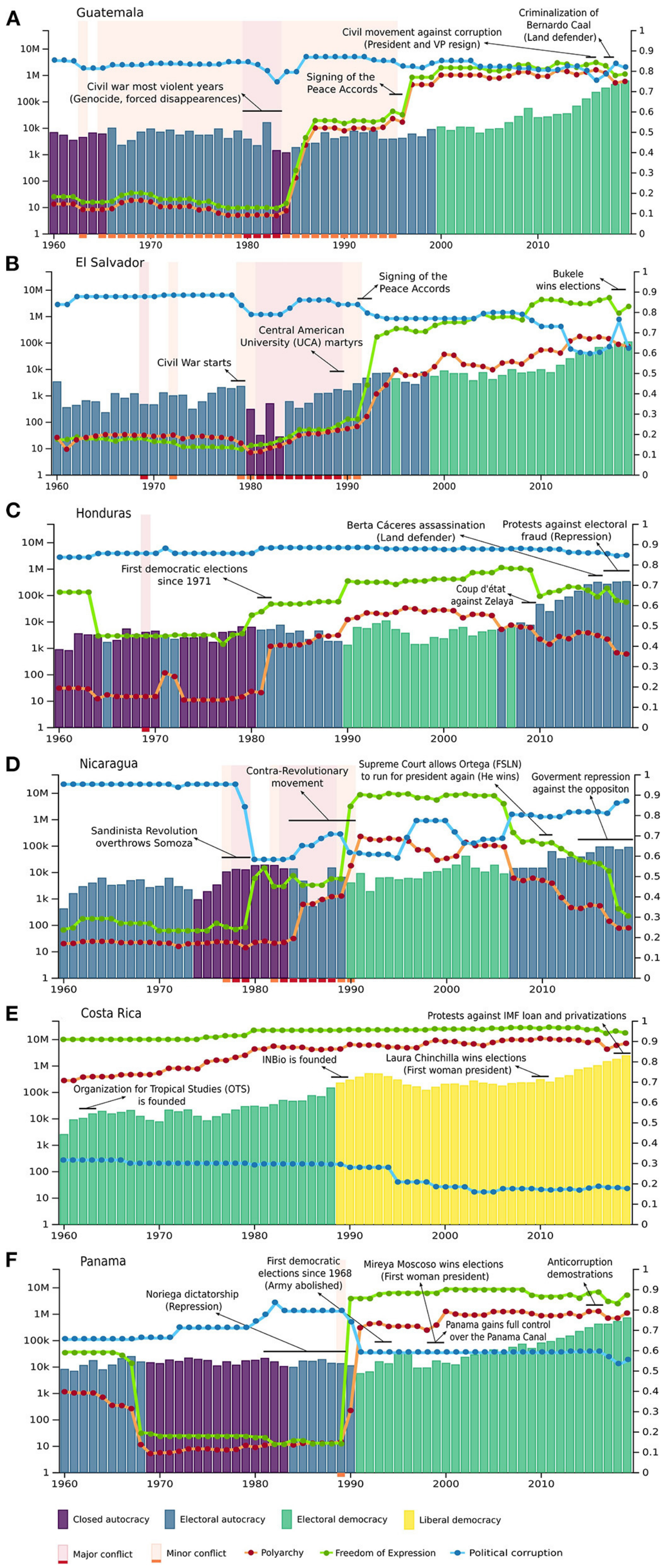

FIGURE 1 | Number of species occurrence records and socio-political variables between 1960 and 2020 in Central America (by Bio-Dem). The three socio-political variables that were considered are (1) Freedom of expression (green), (2) Political corruption (blue), and (3) Polyarchy (red). Polyarchy refers to what degree a

(Continued)

FIGURE 1 | government selects its executive and legislative through popular elections (electoral democracy). Bar colors indicate political regime type, also showing minor and major conflict periods and key historical events for each country. In the case of Guatemala, Bio-Dem did not recognize the genocide as a major conflict, therefore we added the red background in the beginning of the 1980s when the genocide was executed. Note the logarithmic scale for the left y-axis corresponding to the species record number. The right y-axis corresponds to the chosen socio-political variables index.

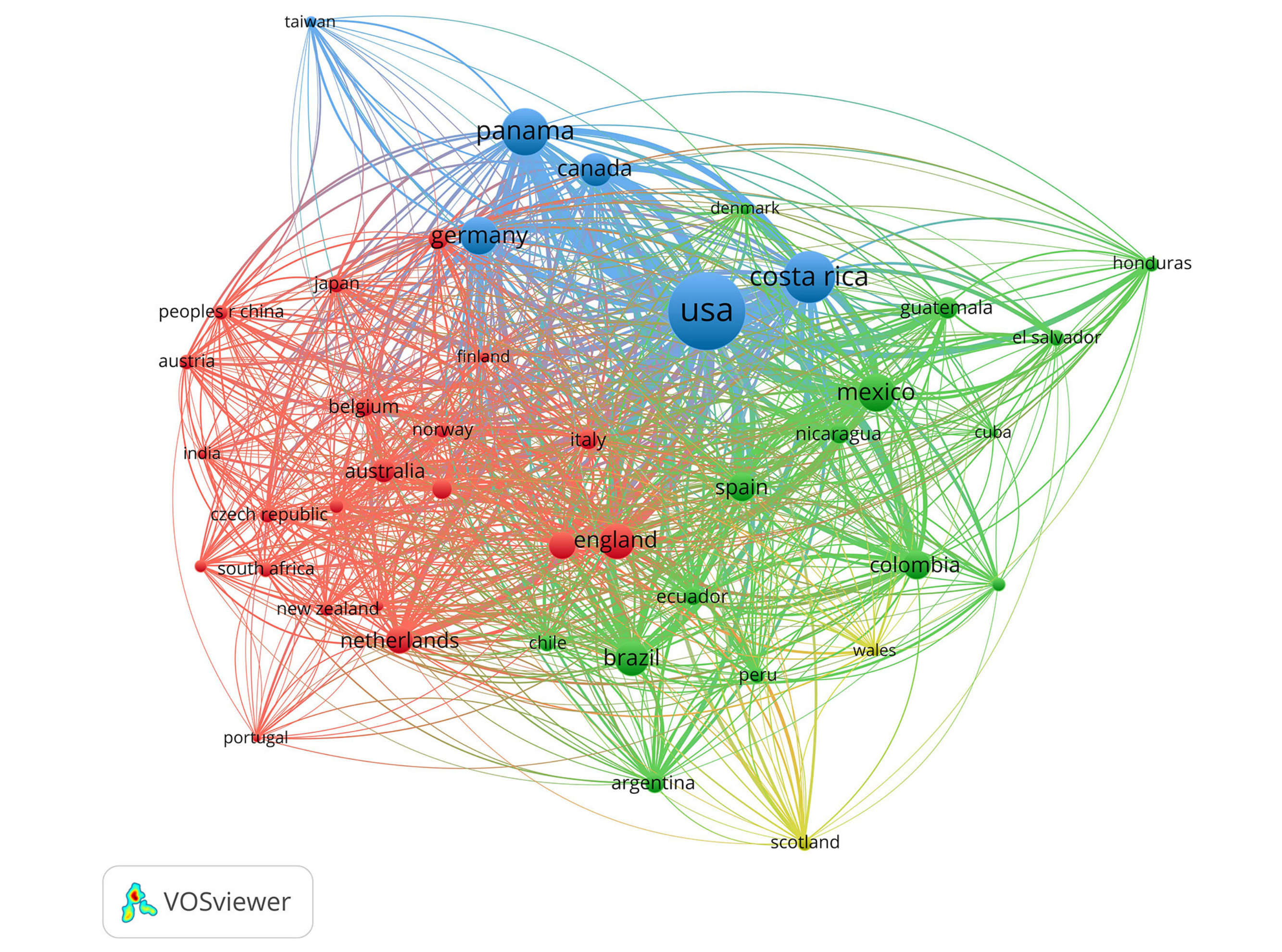

FIGURE 2 | Network visualization map of international research collaboration among top active countries in biodiversity research in Central America. A threshold of at least 30 co-authored publications was applied. The size of the node and connecting line is proportional to the influence of the node in the network (number of publications and collaborations). Color indicates the relatedness of each cluster (by VOSviewer 1.6.18).

with the traits of young post-wars democracies, resulted in an economic crisis heavily felt by the working and middle class, and seized by local economic elites: "Though these policies curbed inflation and eventually resulted in slight economic growth, they inevitably pummeled the poor majority" (Walker and Wade, 2011, p. 97).

These democratic transitions and economic liberalization posed major challenges for the region's scientific production. The weakened institutionality—including research spaces—depended largely on international collaborations to function. Despite all Central American countries having a hyperdiverse landscape and being relatively small with large population density (**Table 5**), the amount of research on the subject does not reflect such reality. It is not the natural resources in a country nor the size of its population which determines how much research is being carried on the matter, but the socio-political context. The following section presents a thorough exploration of how the scientific production in the region has been affected by its convulsed history.

SCIENTIFIC PRODUCTION ON BIODIVERSITY TOPICS IN CENTRAL AMERICA

Bio-Dem and bibliometrics were used to explore possible links between historical democratic variables and the availability of biodiversity data, species records, and scientific production in

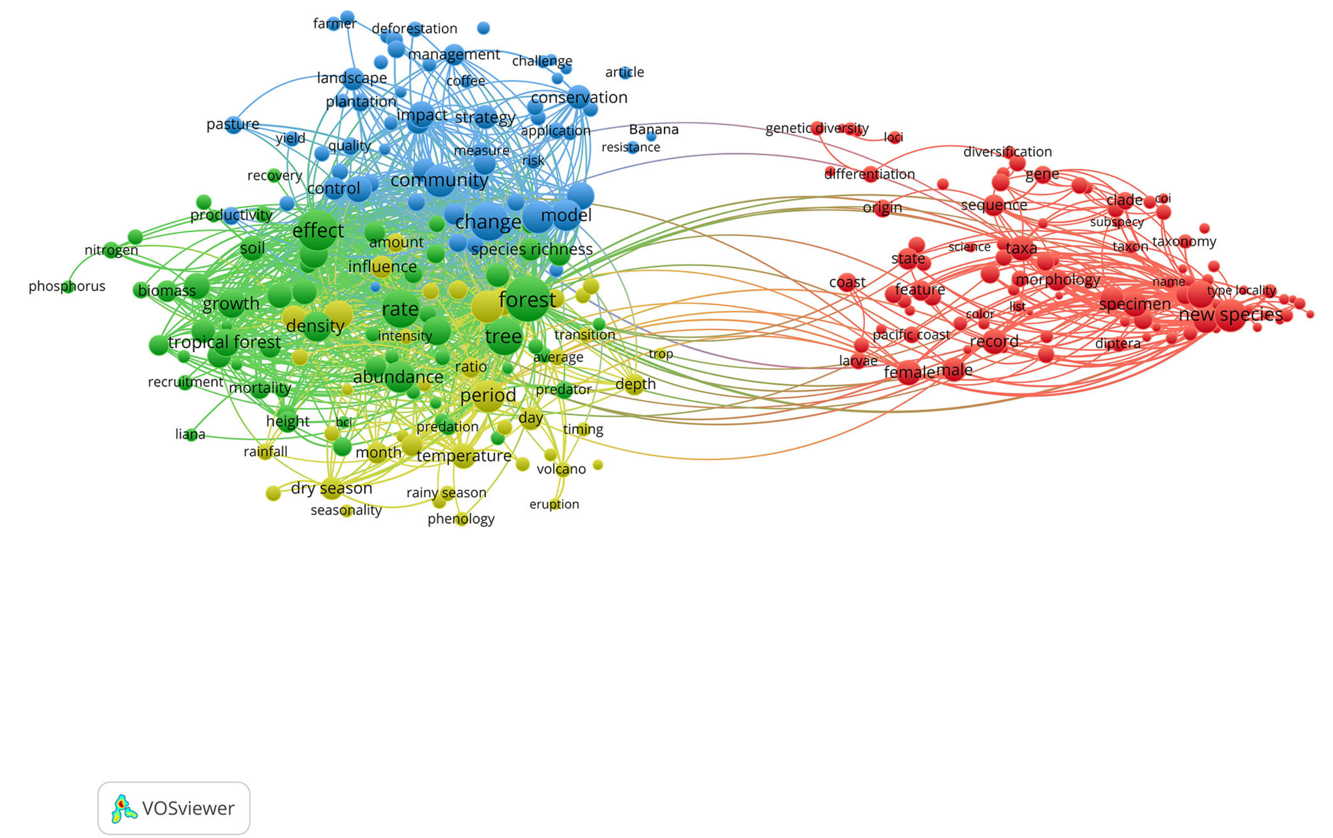

FIGURE 3 | Network visualization map of terms in title and abstract fields of documents in biodiversity topics in Central America. Minimum occurrences of each term was 100. Nodes with the same color represent a cluster of related terms (by VOSviewer 1.6.18).

Central America. The search was based on the publications addressing biodiversity science production in each Central American country from 1980 to 2020. The following entries were obtained per country: El Salvador (538), Honduras (1,059), Nicaragua (1,105), Guatemala (1,701), Panama (4,531), and Costa Rica (7,370). There is a considerable growth rate in every decade being the most productive years from 2000 to 2020 (**Table 1**).

When comparing the number of publications in Central America, there is a noticeable gap between the Northern countries (Guatemala, El Salvador, Honduras, and Nicaragua) versus those from the South (Costa Rica and Panama). The amount of georeferenced species occurrence records in natural collections, herbaria, and biological databases follows the same production tendency (**Figure 1**). Also, the democracy indicators vary per country throughout the years. In the Southern countries, the polyarchy index is higher than in the Northern ones, a manifestation of Costa Rica and Panama's more stable democracies in comparison to the ones in Guatemala, El Salvador, Honduras, and Nicaragua. The differences in the freedom of expression and political corruption values between Northern and Southern Central America also reflect a history of political convulsion and the inadequate structural arrangements that resulted from the region's democratic transition.

Costa Rica and Panama produce almost five times more scholarly works in biodiversity topics than their neighbors, being carried mainly by domestic researchers (local and foreign authors with an affiliation to a local institution). It is necessary to notice that in the first two decades (1980–1999) the research conducted in the Northern countries was led by foreign researchers that did not have an affiliation to a local institution. The top publishing and most influential country in the science production on biodiversity topics of all time in Central America is the United States (US), which is not a surprise given the extent of their funding programmes and the history of interventions in the region.[4]

Panama and Costa Rica are the only two Central American countries with long-running participation in international scientific consortiums as observed in the node size in **Figure 2**. The construction of the Panama Canal under US administration at the beginning of the 1900s led to the creation of the Smithsonian Tropical Research Institute (STRI) in Panama. In the case of Costa Rica, in 1963 the Organization of Tropical Studies (OTS) was founded in cooperation with US scientists

[4]For example, the execution of the operation PBSuccess in Guatemala (1954) to overthrow the democratic president Jacobo Árbenz Guzmán, and supporting the contra-revolutionary movement in Nicaragua (1980–1991) (Torres-Rivas, 2007).

[Organization for Tropical Studies, 2021; Instituto Smithsonian de Investigaciones Tropicales (STRI), 2022]. These partnerships promoted brain gain processes in both countries making foreign researchers establish local affiliations. A great example is La Selva Research Station in Costa Rica which also gave local researchers the possibility to liaise with graduate biodiversity schools. These kinds of interactions and opportunities, limited as they are to having international research counterparts, explain one path the Central American scientific diaspora follows in order to find research opportunities.

We observed that only after the year 2000, science production increased not only in the total amount of publications but also in the participation of local institutions and researchers. This could be partially explained by the seeming improvement of the democracy indicators shown in **Figure 1**. A democratic and stable political environment would attract more investment of all kinds, science production being one of them.

A wider overview of collaboration among other countries with Central America is shown in **Figure 2**. The network analysis was created through VOSviewer, considering co-authored publications and country of affiliation. To refine the collaboration level, a threshold of at least 30 co-authored[5] publications was applied. The TLS related to each country was highlighted proportionally to the size of the corresponding influence in the network, document frequency, and their number of citations (**Table 2**). Three main clusters of countries emerged.

The US showed the highest level of influence in the network (4,652), followed by Costa Rica (2,143), Panama (1,745), and Mexico (1,174). In particular, US authors collaborated on biodiversity subjects with Costa Rican, Panamanian, German and Canadian researchers, respectively. This cluster shows that there is a link between the US and other Central American research institutions, being Honduras and El Salvador the two Central American countries with the least links to international institutions. The second most prominent cluster is the one comprising Latin American countries, in which Mexico, Colombia, Spain (for historical reasons), and Brazil were the most influential countries. The third cluster is the European one, including China, and South Africa to a lesser degree of influence in the network. This link responds to economical and geopolitical connections among these countries, mostly because of science and development funding projects.

Documents published by Panamanian-based researchers ranked first in the number of citations per document (34.5) followed by those published by researchers from Canada (29.0), US (28.3) and England (28.3). This highlights the Panamanian brain gain process and the impact of the STRI on the region. The network also foregrounds the most common destination countries for the Central American scientific diaspora. The United States is the most frequent foreign destination, reflecting its geographical and historical closeness to the region. The network analysis also showed that Costa Rica expresses a high degree of influence in the science production of the Central American Northern countries. Within the region, Costa Rica tends to be the most frequent destination for internal scientific migration.

We created a network analysis of the most influential institutions and a threshold of at least 50 co-authored publications was applied (**Supplementary Figure S1**). The top most influential institutions/organizations for biodiversity science production in Central America were dominated by Smithsonian Tropical Research Institute-Panama-, University of Costa Rica, University of Florida-US-, and National Autonomous University of Mexico (UNAM) (**Table 3**). For Central America, when it comes to science production on biodiversity subjects, only Panamanian and Costa Rican institutions shared the same influence compared to those of foreign countries. The majority of the most influential institutions in regards to biodiversity science production were from the US.

For the most active journals dealing with biodiversity literature, we used a 50-occurrence threshold for network analysis. The leading journals were Biotropica-US-, Ecology-US-, *Revista de Biología Tropical*-Costa Rica-, and the Journal of Tropical Ecology-UK- (**Table 4**). It is remarkable that *Revista de Biología Tropical* (a Spanish/English journal from the University of Costa Rica) was one of the most influential journals in the region (**Supplementary Figure S2**). These results support our vision of how stronger democracies allow political stability for education investment, therefore, science production.

The most frequently used terms in the titles and abstracts of biodiversity scientific production in Central America were mapped applying a threshold of 100 occurrences. The outcome was the emergence of 265 words that were distributed in four clusters (**Figure 3**). The first cluster (red) included items focused on taxonomy, new species description, morphology, systematics, evolution, genetic diversity, entomology, and herpetology. The second cluster (blue) included terms focused on conservation, crops (banana, coffee), landscape, management, deforestation, and plantations. The third cluster (green) included items focused on ecology, soil science, forest dynamics, abundance, species richness. The fourth cluster (yellow) included terms focused on environmental sciences, temperature, dry season, rainy season, volcano, ecosystems transitions, phenology. It is worth mentioning that both of the crops most prominently studied in the publications—banana and coffee—are core commodities of Central America's gross domestic product. These were historically developed through the monopoly exerted by the US enterprise United Fruit Company in the early 1900s, and the German settlers and exporters. The growth of the banana and coffee exportation industry relied on labor force exploitation strategies, land evictions, and collusions between governments and foreign enterprises in the past century (Chomsky, 2021), as a preamble to the state capture phenomenon that emerged by the end of the century through neoliberal guidelines. It is also important to notice the influence that the United States Department of Agriculture (USDA) has had on the region, being one

[5]The threshold of co-authored publications indicates the number of occurrences that the variable (country of affiliation, term, institution or journal) needed to have to be included in the network analysis. In comparison to other studies using VOSviewer like Sweileh (2020), we opted for a larger threshold, allowing for a more in-depth analysis.

TABLE 2 | Top ten publishing countries in biodiversity topics in Central America.

Rank	Country	Frequency	C/D	TLS
1st	United States	6,455	28.3	4,652
2nd	Costa Rica	2,354	15.0	2,143
3rd	Panama	1,264	34.5	1,745
4th	Mexico	1,090	12.8	1,174
5th	Germany	923	24.9	1,135
6th	England	629	28.3	1,040
7th	Brazil	885	14.1	932
8th	Canada	721	29.0	914
9th	Colombia	405	21.8	667
10th	Spain	460	17.1	648
14th	Guatemala	265	15.7	391
17th	Nicaragua	198	18.3	345
26th	El Salvador	130	11.4	193
28th	Honduras	153	9.7	190

C/D, number of citations per document.
TLS, total link strength in the network analysis.

TABLE 3 | Top ten publishing institutions/organizations in biodiversity topics in Central America.

Rank	Institution/Organization	Frequency	C/D	TLS	Country
1st	Smithsonian Trop Res Inst	1,044	44.1	938	Panama/USA
2nd	University of Costa Rica	1,166	9.7	477	Costa Rica
3rd	University of Florida	369	30.7	221	USA
4th	Auto Nat Univ of Mexico (UNAM)	475	14.3	220	Mexico
5th	University of California Berkeley	178	36.6	170	USA
6th	University of Illinois	146	38.6	170	USA
7th	University of Panama	132	12.0	158	Panama
8th	McGill University	105	37.0	122	Canada
9th	University of California St Cruz	106	50.9	119	USA
10th	Cornell University	135	31.5	118	USA

C/D, number of citations per document.
TLS,Total link strength in the network analysis.

of the top publishing institutions for Guatemala in the 1990s (**Table 1**).

CONSERVATION AND CLIMATE CHANGE ON THE ISTHMUS

Both the social and natural landscape in Central America suffered from the implementation of neoliberal policies and, in many cases, these two dimensions were affected at the same time. For example, despite Honduras ratified the International Labor Organization (ILO) Convention No. 169 in 1995, which recognizes the right of the populations to be consulted before extractivist concessions, over the last few years there has been a discussion surrounding a new legislative proposal that redefines the consultation guidelines giving the Government the final decision (International Labour Organization, 2017). This process has had the support of the Inter-American Development Bank (IDB) and the United Nations Development Program (UNDP) (Corea, 2018).

The vast majority of the extractivist projects approved in Central America have arisen social conflict due to the lack of sustainability, legal and social guidelines that could reduce the impact they inflict on the ecosystems and communities. However, such extractive industries have been able to modify laws, obtain environmental licenses and use the judicial representatives to imprison social leaders who oppose their unregulated industrial activities. In sum, they have implemented a corporate state capture strategy. For instance, the criminalization of the maya-q'eqchi' land defender Bernardo Caal in Guatemala who was sentenced in the midst of a high political corruption environment. In Honduras, as well, the indigenous lenca leader and land defender Berta Cáceres was assassinated for defending the Gualcarque River against a hydroelectric

TABLE 4 | Top ten publishing journals in biodiversity topics in Central America.

Rank	Journal	Frequency	C/D	TLS	Country	H-index*
1st	Biotropica	458	36.8	1,981	USA	96
2nd	Ecology	214	96.7	1,544	USA	297
3rd	Revista de Biologia Tropical	1,290	7.5	1,198	Costa Rica	38
4th	Journal of Tropical Ecology	224	36.7	1,169	UK	85
5th	Journal of Ecology	85	120.8	970	UK	181
6th	Oecologia	155	60.1	769	Germany	196
7th	Zootaxa	851	6.4	763	New Zealand	87
8th	Conservation Biology	72	105.9	602	UK	222
9th	Ecological Applications	79	60.9	473	USA	213
10th	Biological Conservation	85	50.3	444	Netherlands	199

C/D, number of citations per document.
TLS, Total link strength in the network analysis.
**Source: Scopus.*

TABLE 5 | Funds assigned for research in Central America.

Country	GDP% allocated to Research and Development, year (a)	No. of researchers per million people, year (b)	Area (Km^2)	Population in millions (c)	Population density in Km^2
Central America					
Costa Rica	0.38 (2018)	345 (2018)	51,000	5,094,114	96.93
El Salvador	0.16 (2018)	71 (2018)	21,041	6,486,201	304.72
Panama	0.15 (2017)	39 (2013)	75,420	4,314,768	55.12
Nicaragua	0.11 (2015)	70 (1997)	130,370	6,624,554	48.53
Honduras	0.04 (2017)	35 (2017)	112,090	9,904,608	83.71
Guatemala	0.03 (2018)	13 (2018)	108,889	16,858,333	158.38
Core-countries*					
US	2.83 (2018)	4,412 (2017)	9,833,520	331,501,080	36.2
China**	2.14 (2018)	1,307 (2018)	9,596,961	1,410,929.36	149.7
UK	1.70 (2018)	4,603 (2018)	242,495	67,215,293	281.18

**Included for comparison purposes.*
***Without including Hong Kong or Macao Special Administrative Regions.*
Source:
(a) World Bank (2019) https://datos.bancomundial.org/indicador/GB.XPD.RSDV.GD.ZS.
(b) World Bank (2021) https://data.worldbank.org/indicator/SP.POP.SCIE.RD.P6.
(c) World Bank (2019) https://data.worldbank.org/indicator/SP.POP.TOTL.

dam project (**Figure 1**). The democracy indicators might show high levels of freedom of expression in comparison to previous decades, and do not display dictatorships as a reality in Central America. However, the State structure that resulted from the democratic transition and was oriented by a neoliberal world agenda, has developed new legal ways of repression and coercion. The state capture phenomenon is not an illegal one, it rather uses legal strategies to promote private interests above public ones. In a region where traits of formal democracy coexist alongside practices and institutions that tend to be part of authoritarian regimes (Desmond Arias and Goldstein, 2010), the government becomes a corrupt mediator between transnational companies and the population. At the same time, refusing to support its decisions on trustworthy scientific production while cutting funding for academic institutions. Academic institutions are perceived as a menace in the context of political instability and lack of democratic guarantees due to their intellectual reflective capacity and their social mobilization potential. In Nicaragua, for example, over the last few months the Ortega regime has closed five different universities (AFP, 2022). This reality shows that, despite being a biodiversity hotspot containing unimaginable possibilities that could offer alternatives for everyday issues, Central American governments do not prioritize research on conservation[6] nor social welfare.

It is important to highlight that climate change is one of the biggest threats to Central America's biodiversity, therefore, to its populations and ways of living. The overpopulation in the region's countries is correlated to the exploitation of its natural resources and the scarcity of their access. It is not a coincidence that the Northern countries, where the extractive industry is more developed and unregulated, are more overpopulated than the Southern ones. For example, El Salvador, which is the smallest country in the region, has a larger population than Costa Rica (**Table 5**). This is a direct threat to biodiversity in each country because larger populations overload the carrying capacity of Central American ecosystems.

In 1988, the United Nations (UN) created the Intergovernmental Panel on Climate Change (IPCC) to promote discussions and agreements that would mitigate the possible effects of environmental changes due to the effects of pollution of large extractive practices. By 1992, the IPCC—which was attended by all Central American countries—agreed to reduce carbon emissions from industrialized countries to stop global warming. In 1997, the Kyoto Protocol called for the reduction of emissions from industrialized nations, and once again all Central American countries signed the agreement. However, the core-countries'[7] political and economic interests prevented the protocol from gaining traction until 2005.

"Between 1998 and 2010 Central America experienced a substantial increase in the recurrence of severe and extreme weather phenomena associated with climate change" (Stein, 2014, p. 64). The IPCC 2014 report remarked on the vulnerability of Central America in the next 50 years, demonstrating how climate change and high levels of deforestation (mainly in Guatemala, Honduras, El Salvador, and Nicaragua) could impact crops production, flooding/droughts, and the frequency of tropical infectious diseases (Magrin et al., 2014). In 2016 all Central American countries signed the Paris Agreement for a long-term temperature goal to keep the rise of global temperature below 2°C above pre-industrial levels. These international pacts should be a top priority in a region that, as explained, is highly vulnerable to climate change.

Further studies and systematic reviews of climate change-related risks for the region have identified contingencies associated with food insecurity, floods and landslides, water scarcity, epidemics, coral bleaching, tropical storms, erosion, and sea-level rise until 2070 (Hagen et al., 2022). These effects have been perceptible in the last years through natural and social phenomena, like hurricanes Eta and Iota that affected more than 7 million people and caused almost $7 billion (AON, 2020) in damage. Also forced migrations phenomena like the Central American Migrant Caravans, more than 7000 people traveling from Central American countries to the Mexico-US border searching for refuge and labor opportunities (Pradilla, 2019). The main cause is disaster displacement, human populations living in fragile ecosystems affected by floods or droughts or/and living in conflict-affected areas with hostile/violent groups like "maras" gangs or drug trafficking. The most affected populations are rural communities, indigenous people, Afro-Latin Central Americans, women, LGBTQIA+ and migrants (Magrin et al., 2014; Hagen et al., 2022).

UNDERSTANDING SCIENTIFIC DIASPORA IN CENTRAL AMERICA

Latin American countries experience scarcity in science funding, such investment is considerably lower in Central America (**Table 5**). During the democratic transition period for the region, the national councils for science and technology[8] were created: Costa Rica in 1990, Guatemala in 1991, El Salvador in 1992, Honduras in 1993, Nicaragua in 1995, and Panama in 1997. This means that before the 1990s Central American countries did not have clear research guidelines nor state funding for it. However, these institutions operate with very little porcentage of the national GDP that is assigned yearly to research and development, which is especially acute for Honduras and Guatemala both the countries with the lowest number of researchers per million people (**Table 5**).

Guatemala and El Salvador, the region's most populated country and the one with the highest population density per km^2 respectively, have only one state university. For the entire region it is safe to say that most higher education institutions are private, adding up to the privatization of democracies' tendency, and commodifying the access to education. In Panama, the mean years of schooling per person is 10.2, while in Honduras and Guatemala it is 6.4 years (PNUD, 2018). These facts are the mere reflection of a deficient educational system, both in regards to quality and access, another outcome of systematic corruption and low democratic indicators (**Figure 1**). Some of the features that the Central American Northern countries share include "the precariousness of their higher education systems (and education in general), the institutional weakness of public bodies and governance relevant to science, technology and innovation and a private (industrial) sector disconnected from the greater national development project" (Bonilla and Serafim, 2021: 24).

The lack of support for STEM careers (Science, Technology, Engineering, Mathematics) from state institutions is one of the fundamental reasons for the underdevelopment of the region's science production (ídem). Advanced biodiversity research like

[6]Some steps in that direction have been given by Costa Rica, El Salvador, and Honduras who forbid open-pit mining in 2011, 2017 and 2022 respectively.

[7]Following Wallerstein (2005) throughout this article, the authors will be using the terms "core-country" and "periphery-country". This must not be perceived as a mere change in the terminology—developed vs in ways of development—, but rather implies a different analytical approach that's informed by the World-system theory and the Dependency theory. That is, the acknowledgment that the idea of development is outdated and presents a false illusion of linear transformations with one sole reaching point molded by industrialized countries. The core-periphery categories refer to unequal exchange dynamics and it places the emphasis on the analysis of historical systems and not on the nation-state category.

[8]Costa Rica is the only Central American country which has upgraded this institutional space to a Ministry of Science, Innovation, Technology and Telecommunications (MICITT).

genomics, transcriptomics, LiDAR technology, bioinformatics, and sampling big areas for instance, requires high financing. There is a lack of graduate schools awarding academic degrees in advanced biodiversity topics like Molecular Biology, Genetics, Advance Ecology, Soil Sciences, Geology, Oceanography, Marine Biology, Environmental Sciences, Forestry, Zoology, Botany, especially in Guatemala, El Salvador, Honduras, and Nicaragua.

Local science production tends to be invisibilized because most domestic professionals only have an undergraduate degree, which means that they are not familiarized with science communication nor peer reviewed publication processes. Scholarships and fellowships for undergrad and graduate students in these countries are almost non-existing, leaving little options to those who want to pursue a career in STEM. The continuation of academic training tends to be abroad, a defining reality of the brain drain phenomenon (Bonilla, 2018). Countries like Panama, for example, have developed repatriation programs (2010) with support from the IDB to foster the return of trained national scientists (Torres-Atencio, 2022). This contrasting scenario for science performance in Central America limits the local research scope in regards to international collaborations, events, publications, and the advance of science in general.

These barriers seem to be less frequent for core-country scientists (global North), to whom pursuing research in Central America (or Latin America) is more plausible than for domestic professors and students. Within the region, Costa Rica and Panama are the only countries with more specialized science research in biodiversity topics, making them a destination for the internal Central American scientific diaspora. This tendency follows what Chinchilla-Rodríguez et al. (2018) posed in their study on scientific mobility, where core-countries showed less collaboration ratios than periphery ones. These ties, as shown in our article, are highly resource-dependent in nation-state contexts of corruption and political instability. The core-countries have historically accumulated resources by means of extraction, colonialism and neo-colonialism, therefore they do not present an urge to have international funding. Their counterparts, on the contrary, are selected upon research interest. There is broad evidence of colonialism having a direct impact on diversity research (Rydén et al., 2020). It appears that species records availability and number of publications is tied to the author's origin. For example, in the Journal of Biogeography (Wiley), the number of publications correlates with the first and corresponding author's nationality. According to the decolonial analysis presented by Eichhorn et al. (2020), out of all the papers published in said journal, Central America ranks amongst the lowest publishing regions in the world.

Tracking scientific mobility in Central America, outside and within the region, remains a challenge. A few governamental databases for tracking local scientists' paths are available, but they have limitations on presenting clear data and statistics that could inform where local scientists are establishing their careers. The most frequent destinations of the Central American scientist diaspora are the US, Mexico, Western-European countries, and to a lesser extent other Global South destinations (Chinchilla-Rodríguez et al., 2018), which is also observed on the network analysis for the most influential countries in biodiversity research in Central America (**Figure 2**).

Latin America and the Caribbean are amongst the most unequal regions of the world [Comisión Económica para América Latina y el Caribe (CEPAL), 2022]. In the case of Central American scientists, taking into account the decades-long democracy instability, they are forced to overcome deep social, cultural and ethnic barriers. All of the advanced scientific production, not just on biodiversity topics, is expected to be produced in English in order to be published in renowned journals. In a region that lacks academic institutions and funding to promote research, local scientists struggle to cover the fees for international publications or even to access specialized and updated literature (Ciocca and Delgado, 2017). According to our analysis, less than half of the science production on Central American biodiversity is open-access. A gender gap bias is also reflected in the disparity of the number of authorship by women authors versus that from men (**Table 1**), which reflects a reality in which manuscripts submitted by men are more likely to be accepted (Valenzuela-Toro and Viglino, 2021). These disparities are accentuated when ethnicity and ableism are taken into consideration.

CONCLUSION

The Central American region is highly vulnerable to climate change effects. Despite the isthmus countries having ratified several international agreements on the matter, their investment on research and science does not reflect it as a priority. Without a state policy oriented toward the promotion of researching institutions (grants, scholarships, fellowships, etc.), trained researchers and scientists that were privileged enough to access higher and specialized education are forced to migrate to pursue professional opportunities. This brain drain phenomenon hinders the development of science based solutions to the Central American countries' most pressing issues.

The low scientific production in Central America is not the result of lack of ability or talent, but rather the outcome of convulsed historical processes that weakened state structures and institutionality, and framed how the populations have reacted to ongoing conflict. This facilitated the capture of the state by local and international economic powers, determining how the resources are distributed through systemic corruption practices. As suggested, scientific production tends to be more prolific when democratic conditions are guaranteed. Despite the barriers encountered by the scientists of the region, the results demonstrate that the research production on biodiversity topics has been steadily increasing over the years. A higher production of biodiversity science was observable in Costa Rica and Panama in contrast to their Northern region neighbors, which again expresses how science advances are built upon strengthened and institutionalized research and stable democratic contexts that allow for collaborations and investment.

This analysis showed that the United States is the country with the tightest academic links to Central America (**Figure 2**) and its biodiversity research production. This country's historical interaction with the region has mostly been through economic/political intervention: the numerous decades of monopoly through the United Fruit Company since the beginning of the 1900s, the contra-revolutionary support in countries like Guatemala (1954) and Nicaragua (1980-1991) which halted democratic processes (Torres-Rivas, 2007), and the construction (1903–1914) and ownership of the Panama Canal by the US until 1999. Taking into consideration such history, the level of US influence on the science being produced about Central America's natural landscape leads to some broader reflections. The fact that most of the publications regarding Central American biodiversity throughout the analyzed decades came from US institutions with no links to local hubs perfectly exemplifies science extractivism, which has become an extension of modern colonialism (Eichhorn et al., 2020; Rydén et al., 2020; Zizka et al., 2021) that continues to deepen dependencies more than fostering collaborations amongst peers. The understanding of science production on biodiversity topics for environmental and social legislation has a direct link to democratic and historical processes.

Our data set for studying biodiversity science production in the region was based on the use of Bio-Dem as a platform that is fed solely by the data presented in the GBIF, and the V-Dem research project. There are other initiatives of citizen science platforms that could be taken into consideration, especially in regards to species records (Feldman et al., 2021). Our bibliometric analysis had some limitations that are worth pointing out. The entries in the WoS database only take into consideration peer reviewed works in English, framing the reach of our exploration. The fact that Spanish writing journals are not considered in WoS database, expresses the bias of science productions in non-English speaking countries. Another limitation was the country of origin of the publication in the bibliometric analysis, which was considered just by the main affiliation of the corresponding author(s) even though some of the other authors might have been from local countries.

Despite these limitations, our work still underpins tendencies that shed light on some of the challenges that scientific production and scientific mobility faces in Central America and their historical causes. Democracy, science, and conservation are core elements that go hand in hand and that need to be nourished in a region that struggles with extractive activities and the protection of life.

DATA AVAILABILITY STATEMENT

The original contributions presented in the study are included in the article/**Supplementary Material**, further inquiries can be directed to the corresponding author/s.

AUTHOR CONTRIBUTIONS

JM-M conceived and coordinated the study, carried out the bibliometrics and network analysis, and explored the Bio-Dem tool. RS led the historical and political analysis. JM-M and RS designed and drafted the manuscript. MZ and JB contributed to the edition and funding of the article. All authors read and approved the final manuscript.

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BRIEF RESEARCH REPORT
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Developing a Digital Technology System to Address COVID-19 Health Needs in Guatemala: A Scientific Diaspora Case Study

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Scientific diasporas are organized groups of professionals who work together to contribute to their country of origin. Since the start of the COVID-19 pandemic in 2020, scientific diasporas around the world have focused their efforts to support the public health response in their countries of origin. As the first cases of COVID-19 were reported in Guatemala in March of 2020, a team of four Guatemalan nationals, residing abroad and in-country, started collaborating to tackle COVID-19 misinformation and issues with healthcare services navigation. Their collaboration was facilitated by FUNDEGUA, a Guatemalan nonprofit, which provided a legal framework to establish partnerships and fundraise. The team created a digital technological system called ALMA (*Asistente de Logística Médica Automatizada* in Spanish). A female character named ALMA was created to personify the digital information services, through social media profiles, an interactive website, a free national multilingual call center, and an artificial intelligence-based chatbot. More members joined the nascent interdisciplinary diaspora through professional/personal references or social media. ALMA provided a platform for Guatemalan nationals to contribute with their skillset to their country during a global crisis through flexible schedules and short- or long-term involvement. As the team grew, the services for query resolution and information dissemination expanded as well. The ALMA initiative shows that scientific diasporas can provide an avenue for professionals to contribute to Guatemala, regardless of their residence and job commitments.

Keywords: scientific diasporas, COVID-19 pandemic, technology, chatbot, Guatemala, capacity building, brain circulation

INTRODUCTION

Scientific diasporas are networks of professionals who reside abroad, have had experience working or studying abroad, and strive to contribute to their country of origin through their work in science, technology, or engineering industries (Séguin et al., 2006). Most diaspora members are citizens of low- and middle-income countries (LMICs) and live in the G-20 nations as these countries host more than 60% of the migrants worldwide (Beirens et al., 2021). Diaspora members contribute, in the form of remittances, transfer of knowledge, and innovations (Beirens et al., 2021), providing LMICs with access to highly skilled workers (Séguin et al., 2006). While highly skilled migrants and diaspora members are often motivated to contribute to their country of origin, they face several barriers, such as time constraints, financial hurdles, poor infrastructure for knowledge transfer, unclear needs, or requests from their country of origin to contribute, and concerns that their lack of seniority in their field could pose a challenge to their credibility as a project leader (Séguin et al., 2006).

On the 13th of March 2020, the World Health Organization declared the novel coronavirus 2019 (COVID-19) a pandemic (World Health Organization, 2020). By then, COVID-19 had spread around the world with over 400 million confirmed cases (World Health Organization, 2020). To deal with the ongoing pandemic, researchers across the world raced to develop a vaccine. By May 2020, approximately 115 COVID-19 vaccine concepts were being developed and a few (5–6) were in human clinical trials (Ciotti et al., 2020). The Food and Drug Administration (FDA) approved the first COVID-19 vaccine for emergency use in December 2020 (US Food Drug Administration, 2020). As of today, over 1 billion vaccine doses have been administered (World Health Organization, 2022).

Over the last decade, digital and mobile technologies have revolutionized multiple industries and transformed many aspects of daily life (Budd et al., 2020). This transformation became even more apparent during the COVID-19 pandemic when digital technological solutions, which could be deployed faster and at larger scales than manual solutions, were necessary for efforts to contain the virus (Whitelaw et al., 2020). The rapid growth in the mobile technology sector was one of the determining factors in the fast democratization of these technological solutions (Budd et al., 2020). In 2019, 67% of the global population subscribed to mobile devices (Budd et al., 2020). Since the start of the pandemic, digital innovations have been used to manage and respond to the COVID-19 crisis. Applications have included disease screening, contact tracing, quarantine and self-isolation, and clinical management software (Whitelaw et al., 2020).

The novelty and threat of COVID-19 led to the rapid development of large amounts of scientific evidence and unchecked information. Public communication of accurate and updated scientific evidence became a challenge. Based on this and fueled by their desire to give back to their country, two Guateleman engineers residing in Guatemala proposed to create an artificial intelligence-based chatbot that could answer COVID-19 questions from multiple people at once, and that could be updated as the new scientific evidence arose. They partnered with two Guatemalan scientists with clinical and epidemiology expertise who were residing abroad. Together they decided to implement this idea capitalizing on their membership with FUNDEGUA (in Spanish, the abbreviation stands for Fundación Desarrolla Guatemala para la Salud y Educación), a Guatemala-based foundation founded by two Guatemalans and a Duke University professor in 2015. FUNDEGUA's goal is to channel its academic, network, and financial resources to support research-based development initiatives in Guatemala. The foundation was inaugurated with a chronic child malnutrition project, funded by the Guatemalan Tigo Foundation and Duke University, and through Duke students led a capacity-building effort of Tz'utujil (Mayan) scientists and local health promoters, who continued the research and implementation efforts. Since then, FUNDEGUA has spearheaded evidence-based healthcare and education projects that foster collaborations between Guatemalans residing abroad and in-country, leading up to the creation of the ALMA (which stands for its Spanish full name, Asistente de Logística Médica Automatizada) initiative. The non-profit offered staff and resources to support the development of this new idea.

In this article, we describe the consolidation of an interdisciplinary diaspora of Guatemalans, residing in-country and abroad, who developed the digital health system ALMA founded and implemented as a public-private partnership between a Guatemalan non-profit and Guatemala's public health system. This diaspora solidified as its members came together to contribute to the pandemic response by creating a system to disseminate evidence-based COVID-19 information at scale to prevent and manage COVID-19 at the individual and community level. We describe the professional backgrounds, motivations, and organization of team members to join this effort supported by the existing Guatemalan non-profit FUNDEGUA. Finally, we analyze the successes and limitations of how this diaspora was formed and discuss the lessons learned so they can serve as examples for other global diasporas in LMICs.

METHODS

Setting

ALMA was developed by a scientific diaspora of Guatemalans. Guatemala is a Central American country with 18 million people, half of whom are Maya-indigenous. In addition to Spanish, there are 22 indigenous languages. While the nation was recently categorized as an upper-middle-income country, this economic indicator masks wide social and economic inequalities and slow progress in human development indicators (Class et al., 2020). In fact, Guatemala lags behind the Latin American region in terms of human development (Class et al., 2020). With one of the lowest public health investments (1% of the gross domestic product) and one of the lowest densities of healthcare workers (12.5 per 100,000 population) in the region, Guatemala's public health system was ill-prepared to respond to the COVID-19 pandemic (Avila et al., 2015; CEPAL, 2020). While the public health system is meant to provide universal coverage (Becerril-Montekio et al., 2011), even before the COVID-19 pandemic (1995–2012), out-of-pocket healthcare spending consistently represented over half of the total health expenditure (Class et al., 2020). In contrast, in Guatemala subscriptions to mobile devices are above 110 per 100 people since 2015 (World Bank, 2022), although this number does not reflect potential disparities between rural and urban populations.

After the first case of COVID-19 was detected in Guatemala on March 13, 2020, multiple surges of COVID-19 have overburdened the healthcare system, leading to more than 600,000 registered COVID-19 infections (Garcia, 2021), more than 16,000 confirmed deaths (Garcia, 2021) by February 2022, and significantly increased excess mortality rates compared to previous years (Martinez-Folgar et al., 2021). Most public health information about COVID-19, including vaccinations, has been disseminated in Spanish. Vaccination efforts have been slow, with estimations showing that by February 2022, about 30% of the population had received two doses, one of the lowest coverages in the Latin American continent (Johns Hopkins, 2022). The distribution of COVID-19 vaccines has been characterized by marked inequalities, with reports showing that more than 65% of Guatemala City's population have received two vaccination doses, compared to less than 30% among indigenous populations living in the rural departments (Lab de datos, 2022).

Data Collection

FUNDEGUA's administrative records were used to describe the members of this scientific diaspora who contributed to the creation of ALMA. This data is collected every time someone joins the team and is renewed annually by the administrative team through a Google Form survey. Approximately five volunteers did not reply to the latest survey and were excluded from the analysis. The database provided by FUNDEGUA was de-identified (names, addresses, emails, and phone numbers were removed) and exported in csv format. The following variables were shared: gender, age, Guatemalan department of origin, highest academic degree, area of specialization (studies), countries where they have experience studying in, role within ALMA, the initial connection to ALMA, motivations for joining the team, prior experience in social impact projects, Guatemalan departments they have experience working in, and country they were residing in when they joined. We also utilized administrative data from meeting minutes to identify and describe the principles, partnerships, strategies objectives of the ALMA initiative.

Data Analysis

The database was cleaned and aggregated using Python (Van Rossum and Drake, 2009). The raw data output had flattened responses, meaning that questions that allowed for multiple responses had a column per possible response, each column name equal to the answer choice. Single response questions had a single column with the corresponding answer. We used the Pandas (McKinney, 2010) Python package to import the csv file into a data frame format. We split each question into two data frames, single response questions and multiple response questions. For single response questions, each answer was summed and divided by the total answers to obtain the response percentage. For multiple response questions, a data frame including the columns which represented the questions' responses was created. Then each column was summed and divided by the total to obtain the percentage. Finally, each data frame was shared to create the output table using Microsoft Excel.

Data Visualization

The principles, partners, strategies, and objectives were portrayed in a Figure using Adobe Illustrator 2020. The distribution of team members across the world based on where they studied and where they resided in before joining the project was portrayed through a chloropleth global map generated in Datawrapper and further edited using Adobe Illustrator 2020. The Guatemalan departments where the team members had experience working in prior to joining ALMA were depicted using a chloropleth Guatemala map generated in Datawrapper.

RESULTS

ALMA Initiative

Figure 1 describes the principles that guided the creation of ALMA, the collaboration between multiple partners, and the strategies employed to reach the key objectives of this initiative. Results on the implementation and impact outcomes of ALMA will be reported in a separate publication.

The ALMA initiative is founded on principles (see **Figure 1**) that enabled collaborations between members residing abroad or in-country to leverage technology in response to the global problem of COVID-19 misinformation. ALMA is backed by a multidisciplinary (see **Table 1**) and collaborative team, that worked remotely, respecting social distancing protocols, and enabling participation from members residing in different countries. The team focused on rapidly prototyping different approaches to the misinformation problem, getting feedback directly from end-users for future iterations. The work was driven by social impact and focused on improving access to available health services in Guatemala. Lastly, the team focused on strengthening existing health system capacities by working alongside the government's efforts to address the needs of the COVID-19 pandemic.

Partners provided guidance and mentorship in the rapid prototyping phases, established collaborations legitimizing the nascent initiative, and provided funding to pilot, implement, and scale their impact (see list of partners in **Figure 1**). Bilateral aid agencies provided funding through all stages of development. Academic institutions helped by providing technical expertise. Working with government institutions was essential to scaling their impact across larger segments of the population. The Ministry of Health and Social Assistance was instrumental in providing the required endorsement for ALMA to work with public health services and providers. Non-profits enabled the ALMA initiative to establish local partnerships and introduce its services outside of urban centers to underserved, indigenous populations. Media outlets helped by providing free and wide dissemination of the services provided by ALMA to the population. Guatemalan student volunteers from U.S. and Guatemalan universities contributed through short-term experiences with their technical expertise.

The ALMA initiative employed strategies to accomplish key project objectives. The team first focused on accomplishing objective 1, providing actionable healthcare information to guide users in their decision-making, for example: when to get a PCR or antigen COVID-19 test based on exposure date, booster eligibility based on primary schedule, latest country guidelines for quarantine after exposure, among others. This information was disseminated by an artificial intelligence-based chatbot in Spanish through social media accounts and a free national

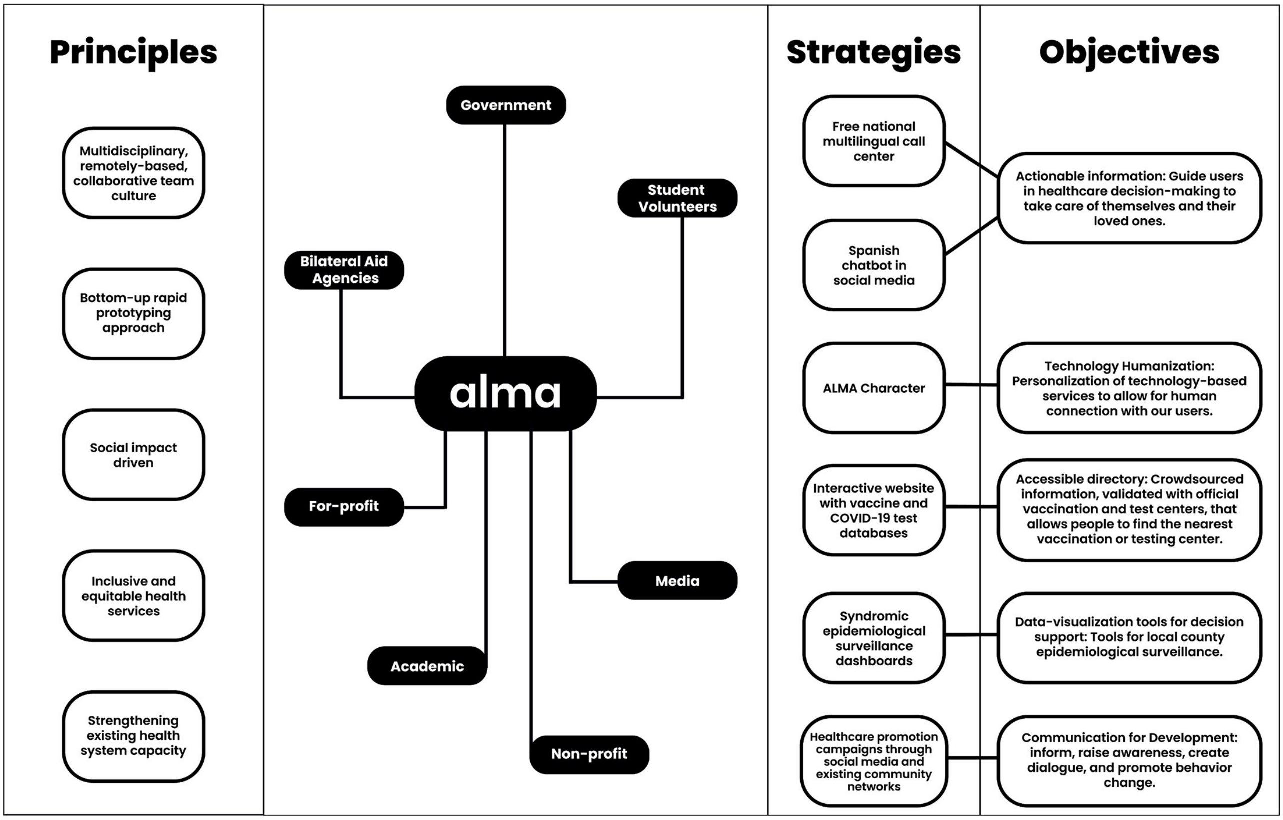

FIGURE 1 | Principles, partners, strategies, and objectives. Principles guide the internal and external collaborations; partners contributed to the strategies implemented to reach the objectives. Bilateral Aid Agencies: CDC, BID Lab, BID Guatemala. Academic institutions: Universidad del Valle de Guatemala, Laboratorio de Datos. Government institutions: Ministry of Health and Social Assistance, National Secretariat of Science and Technology, Vice Presidency, Ministry of Education, Plan Trifinio. Non-profit organizations: Asociación de Salud Integral, Volunca, Wuqu'Kawoq-Maya Health Alliance, FUNDESA, La Ruta. Media: Agencia Ocote, Publinews, Radio Infinita, Radio La Mega, Diario de Centro América, La Red. For-profit organizations: Tecniscan, Allied Global, Pronto BPO. Student Volunteers from: Universidad de San Carlos, Universidad de Rafael Landivar, Universidad Francisco Marroquín, Georgetown University, Universidad del Valle de Guatemala, George Washington University, Notre Dame University.

multilingual (Spanish and five Mayan languages) call center in coordination with national and local healthcare authorities. To establish trust with users, the team personalized the technology employed to deliver the informational services with a friendly character. The character was the result of internal workshops to define qualities that embodied the service the team wanted to provide its users. Additionally, as part of the national vaccination efforts, ALMA created the website www.vacunasgt.com which contains updated information regarding vaccination centers' locations, eligibility requirements, schedules, and wait times. The information is updated through triangulation of official government information and crowdsourcing of live reports from users, volunteers, and staff at vaccination centers. The data collected through ALMA's different channels, such as suspected cases identified through syndromic surveillance, was aggregated, and visualized through dashboards for healthcare authorities, as a support for their decision-making. Lastly, the social media profiles of ALMA were used as mediums to disseminate healthcare promotion campaigns to promote behavior change.

ALMA Multidisciplinary Team

ALMA's team includes members specialized in digital technology, clinical medicine, communication, customer service, business administration, management, and education. ALMA's administrative information shows that the entire team is composed of Guatemalan nationals, aged 19–38 years, the majority born in Guatemala City and highly educated (see **Table 1**). The majority were recruited to join ALMA, either through personal/professional relationships with current team members/co-founders or through ALMA's presence on social media. Lastly, most members (66%) have had prior experience in social impact projects in Guatemala. The 34% of the team members who didn't have prior experience have identified barriers such as lack of awareness of opportunities, lack of time, and conflict with prior job/commitments (see **Table 1**).

ALMA's team members have reported multiple enablers for joining this scientific diaspora while working on another full-time job and residing abroad or in-country. Enablers include: 1) a platform that allowed short-term participation with the

TABLE 1 | Key characteristics of ALMA team members.

Characteristic (n = 29)	Percentage
Gender	
Female	48
Male	52
Current age (ranged from 19–38)	
19–22	14
23–26	38
27–30	31
31–34	10
35–38	7
Guatemalan department of origin	
Guatemala	91
Chiquimula	3
Sacatepéquez	3
Jutiapa	3
Highest academic degree	
High School	10
Bachelor	52
Master	34
Doctorate	3
Area of specialization *	
Technology	28
Health	24
Communication	24
Other	17
Politics	10
Administration	10
Education	3
Role within ALMA *	
Technology	28
Clinical	24
Communication	24
Customer service	24
Administration	10
Management	10
Education	7
Initial connection to ALMA*	
Personal/professional reference	83
Social media post	24
Job posting	3
Other	3
Prior experience in social impact projects	
Yes	66
No*	34
Lack of awareness of opportunities	60
Lack of time	20
Conflict with prior job/commitments	10
Other	10

Information was obtained from ALMA's administrative records. Percentages are reported. Data items marked with an asterisk indicates that participants had the option to select multiple answers for those questions.

possibility for a large impact amplified by an established team, 2) a Guatemalan foundation that backed the project providing a legal framework for its execution and fundraising, 3) the possibility to work remotely in a flexible environment, allowing members to contribute to their country of origin.

ALMA team members have a diverse set of experiences and training abroad and in-country, with more than half studying outside of Guatemala, the top three nations being three income countries, the United States, Taiwan, and Spain (see **Figure 2A**). As displayed in **Figure 2B**, 62% resided in Guatemala when they joined ALMA, 24% in the United States, 3% in Spain, 3% in France, 3% in Ireland, and 3% in Taiwan. Currently, 91% of the team members are residing in Guatemala, 3% in the United States, 3% in Spain, and 3% in Canada. As the initiative advanced, there was a shift from members residing abroad to in-country (62 to 91%), mostly attributed to the COVID-19 pandemic motivating members to be closer to their family during uncertain times, job security, and education opportunities abroad being shut down.

Efforts were made to recruit people residing in the country because it was important to have availability to travel to rural locations to better understand the misinformation problem in Guatemala. **Figure 3** shows the experience ALMA team members had working in different Guatemalan departments (15 out of the 22 are represented), which was crucial for the implementation of the project outside urban centers and the capital city.

DISCUSSION

The ALMA initiative showcases an example of the consolidation of an interdisciplinary diaspora of Guatemalans residing abroad and in-country at the start of the COVID-19 pandemic. Founded upon a loosely connected group of computer engineers and physician-scientists and facilitated through an existing non-profit organization, the diaspora behind ALMA solidified to tackle the global problem of COVID-19 misinformation. Based on successful cases in other countries in Latin America (Panamá, México, Colombia, Brazil) (Albert Einstein - Sociedade Beneficente Israelita Brasilera., 2020; El Universal., 2020; Ministerio de Salud de Colombia., 2020; Ministerio de Salud de la República de Panamá., 2020; Secretaría de Salud de México., 2020), the team created its first minimum viable product, a chatbot, with the following objectives 1) information delivery about COVID-19 symptoms, management, and feasible prevention practices, and 2) first-line triage to differentiate high and low-risk patients based on reported symptoms, epidemiological risk (travel and exposure history) (Lifespan., 2020; Patel et al., 2020; Smith and Boslett, 2020).

The global COVID-19 crisis spurred collaborations among migrants and diasporas around the world to respond to the crisis and support their families and communities "back home" (International Organization for Migration, 2020). On one hand, rapid and significant changes to the global landscape have tested diasporas' capacity to continue fostering development and innovation in their countries of origin (Beirens et al., 2021). Reports have described COVID-19-related factors, such as reduced employment opportunities in the G-20 countries and limited mobilization between countries, as potential threats to diasporas' sustainability and capacity to continue collaborating with their countries of origin (Beirens et al., 2021). Simultaneously, members of diasporas have reacted by

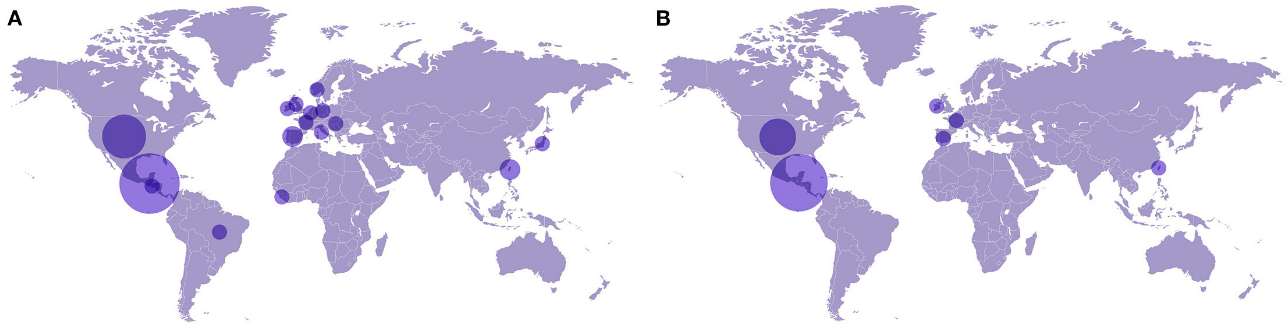

FIGURE 2 | Distribution of the countries ALMA team members have experience studying and residing in. **(A)** shows the countries where team members have studied. **(B)** shows the countries where the team members resided when they joined the ALMA team. The larger circle size represents a larger number of team members for each country.

supporting and connecting with each other and their families and communities back home, proving their resiliency, creativity, and reaction capacity to continue transferring innovations, knowledge, and technology (Beirens et al., 2021). Diasporas have capitalized on existing organizations and associations or created new collaborations to contribute to the response to COVID-19, particularly in the areas of digital technology and health (International Organization for Migration, 2020). Due to the COVID-19 restrictions, collaborations among these diasporas transitioned into online channels, diminishing the barriers of having to travel to meet in person (International Organization for Migration, 2020). This new work-from-home norm allowed the expansion of existing diasporas and the creation of new ones (International Organization for Migration, 2020). The International Organization of Migration developed a report highlighting several diaspora-led initiatives, developed during the COVID-19 pandemic (International Organization for Migration, 2020). In this context, our diaspora of Guatemalans based abroad and in-country emerged to create ALMA. This interdisciplinary group represents technology, communication, social and health science, public policy, and clinical expertise. Members were motivated to join as a contribution to their country of origin during a time of acute need, a possibility to join a group of young and like-minded individuals, for professional development, and because of the flexibility for remote, short-term, or part-time engagement.

Lessons learned from creating this interdisciplinary diaspora include partnering early on with an in-country organization with a track record of supporting similar initiatives and having existing in-country partnerships. This allowed for the rapid development, implementation, dissemination, partnerships, and fundraising for the ALMA initiative. Additionally, providing new members residing abroad or in-country with remote work and flexible schedules, allowed the team to attract talent for either short periods of time or for highly specialized projects within the initiative. A clear social mission that resonated with young professionals, was an instrumental motivating factor for the rapid escalation of the team and for the engagement of diverse partners. The initiative also provided opportunities for university students to join part-time, for their professional development and as an opportunity to give back to their country of origin.

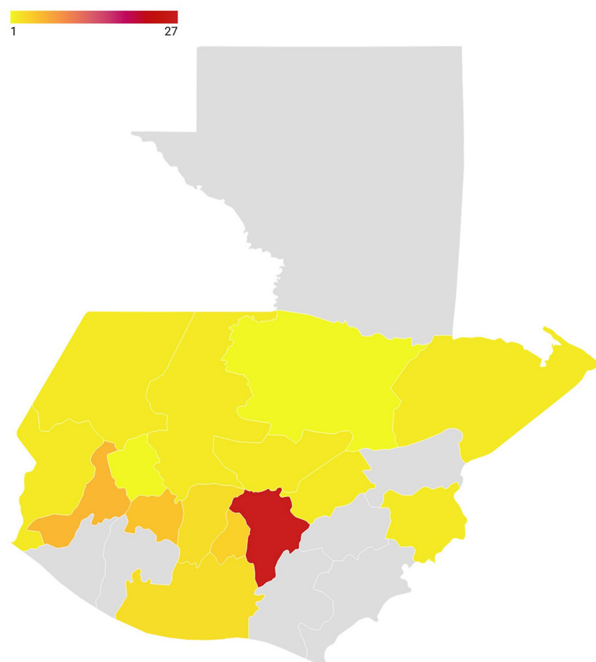

FIGURE 3 | Guatemalan departments where ALMA team members have work experience. Some team members have had experience in more than one department. The minimum was 1 person and the maximum was 27 people with experience working in a particular department. A darker red color corresponds to the maximum number of team members ($n = 27$), and a lighter yellow color to the minimum ($n = 1$). Gray indicates that none of the team members have had work experience in that department.

Future considerations include defining a formal recognition or retribution for all of the team members that had short-term engagements in the initiative. This strategy was necessary given that the team was growing rapidly as digital technological solutions were being developed, and there were no clear benefits after concluding your participation within ALMA. Additionally, the initiative started recruiting more members residing in-country with job experience in multiple departments (15 out of 22 departments are represented), to ensure ALMA could transcend beyond the urban centers and capital city, reaching rural and underserved communities. Over time this reduced the efforts within ALMA to engage Guatemalans residing abroad and keep offering opportunities for involvement in short-term specialized projects, which were more emphasized at the beginning of the initiative's creation. More than half of the team members had experience studying and residing abroad prior to joining and 30% moved back to Guatemala throughout their involvement in ALMA.

The ALMA initiative is currently focused on expanding beyond COVID-19, to continue providing reliable, trustworthy, and timely information about personal health, while generating aggregated epidemiological data that can aid decision-making. In partnership with the Ministry of Health and Social Assistance, the initiative provides information on all vaccines, water and foodborne illnesses, and acute respiratory infections. We are working with non-profits and academic partners to expand to non-communicable diseases (malnutrition), vector-borne diseases, and sexually transmitted diseases. This award-winning initiative has been successful at channeling knowledge, abilities, connections, and resources from Guatemalan nationals living overseas partnering with local scientists, engineers, technicians, and public and private institutions. The result has been a network of like-minded individuals that have led to collaborations beyond the ALMA initiative, in education, mental health, and artistic endeavors.

DATA AVAILABILITY STATEMENT

Administrative datasets were used. Requests to access these datasets should be directed to admin.alma@fundegua.org.

AUTHOR CONTRIBUTIONS

GA, AP-A, JA, and XL contributed to the conception and design of the manuscript and wrote sections of the manuscript. JA and GA wrote the first draft of the manuscript, reviewed the administrative records, and built the table. XL created the figures. AP-A contributed substantially to the conceptualization of the manuscript and critically reviewed the final version. All authors contributed to manuscript revision, read, and approved the submitted version.

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Scientific diasporas and the advancement of science diplomacy: The InFEWS US-China program in the face of confrontational "*America First*" diplomacy

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The challenges and consequences of climate change have brought together governments around the world to advance scientific knowledge and programmatic actions to develop mitigation strategies while promoting sustainable development. The United States and China—the countries with the highest science expenditures globally—have historically developed a range of joint international research collaborations. However, under the "*America First*" agenda put forth by the Trump Administration, bilateral diplomatic relations with China reached their highest confrontational peak. Under this scenario science diplomacy served as a catalyst to maintain scientific collaborations between both countries. In 2018, the US National Science Foundation and the China National Natural Science Foundation launched the InFEWS US-China program to promote collaborations to expand food, energy, and water nexus (FEW Nexus) research and applications. Over the past four years, 20 research projects have been awarded from the US side and 47 publications have been reported as research output. By carrying out a descriptive analysis of the InFEWS US-China research and scholarly outputs, we find evidence of the crucial role played by the Chinese scientific diaspora who led 65% of the projects awarded. We find that there is a generally good understanding of the interdependencies between FEW systems included in the project abstracts. However, in the InFEWS US-China scholarly outputs generated to date, there is a lack of usage of a clear FEW Nexus theoretical framework. Further research should address intentional policies that enhance the involvement of scientific diasporas in their home countries to better address climate, sustainability, and development challenges.

KEYWORDS

science diplomacy, diplomacy for science, scientific diaspora, WEF nexus, climate change

Introduction

The US Presidential Administration of Donald Trump formally withdrew from the Paris Climate Agreement in June 2017, arguing that the commitments that it entailed were unfair to the American economy (Shear, 2017). The reasons used to justify this decision were based on the calculated cost of US$ 3 trillion in lost GDP and 6.5 million jobs in comparison to, it was claimed, more benevolent treatment received by emerging economies such as China and India (Matt McGrath, 2017). This decision threatened the collective efforts made by the international community to tackle the effects of climate change, mostly centered on strategies to reduce greenhouse gas emissions. In addition, based on his now trademark motto "*Make America Great Again*" (and "*America First*"*)*, Trump enacted a wide range of Neo-Nationalist policies with widespread impacts including those that greatly affected higher education institutions and research centers. Some actions included restrictive visa policies for students and professors as well as other anti-immigrant decrees beyond the education sector, anti-science rhetoric including the denial of the effects of climate change, and diminishing the attention and funding for programs to mitigate the severity of the COVID-19 pandemic (Douglas, 2021).

On the international diplomatic stage, relations between the US and China were at their highest confrontational peak under the Trump Administration (Beitelman, 2020). The "*America First*" Neo-Nationalist policies triggered a trade war against China by imposing, for example, tariff and non-tariff restrictions on Chinese imports. Furthermore, Trump accused China of theft of intellectual property and espionage through technology, telecommunications, and electronics companies in China, among many other actions (Boylan et al., 2021).

In the face of the diplomatic confrontation that these presidential decisions triggered, one science diplomacy mechanism stood out between the US and China in the field of climate change, specifically in relation to the food-energy-water nexus (FEW Nexus, also referred to as the WEF Nexus). The US National Science Foundation (NSF) partnered with the China National Natural Science Foundation (NSFC) in 2018 to launch the "Innovations at the Nexus of Food, Energy, and Water Systems (InFEWS: US-China)" program. An extension of NSF's broader InFEWS program that was launched in 2016, InFEWS US-China constituted the only sub-program that was carried out in partnership with a foreign government. Interestingly, NSF's domestic US InFEWS program has awarded in total 96 grants since 2016, while InFEWS US-China has awarded 20 from 2018 to 2022 as part of this total. This means that in just four years this bilateral program represents 21 percent of the total number of projects from the overarching strategy. It is important to understand why this program has been so effective in terms of awarding proposals and also how this program has served to advance research that addresses critical environmental sustainability challenges based on the FEW Nexus.

In this context, this paper will address three main research questions. First, what is the role played by the US-based Chinese scientific diaspora in promoting collaborations with scholars and institutions within China? Second, to what extent did the research projects approved by InFEWS US-China use the FEW Nexus concept, and did they adequately address the interdependencies among all three systems? Third, based on a review of all the publications reported to NSF by InFEWS: US-China projects as of April 2022, how did research teams use the FEW Nexus concept and how did their results contribute to the body of knowledge in this field?

In what follows, we present a brief history of the Sino-American research and scientific collaborations to elucidate how the InFEWS US-China extends a trajectory of binational diplomacy for science programs. Next, we discuss science diplomacy in light of the FEW Nexus conceptual framework, in particular, to assess whether integrated resource assessment and management might be more amenable to science diplomacy collaboration than, for example, a purely physical science approach. In the following section, we present the empirical research based on a descriptive analysis of data from the NSF website complemented by a SCOPUS dataset assessment using bibliometric information on the research output of all InFEWS US-China projects. This is followed by an analysis and discussion of findings, with specific attention to the research questions, as well as recognition of (1) the significant participation of Chinese scholars in the US as InFEWS US-China principal investigators, (2) the substantial partnerships developed with Nanjing Agricultural University, and (3) mixed success in understanding and usage of the FEW Nexus framework. Finally, in the conclusions, we synthesize the role of science diasporas in advancing science diplomacy, especially in the face of confrontational binational diplomacy.

Brief history of Sino-American research and scientific collaborations

Chinese advanced scientific methods predated European and European-American advancement in many areas serving as a source of technological inspiration in the West (e.g., from pottery to textiles). Some authors, however, have documented formal Sino-American Science and Technology relations back to the Nineteenth century when US missionaries played the role of agents for transferring knowledge from science and engineering (Suttmeier, 2014). According to Suttmeier, in the first half of the twenteeth century, there was a fluid and growing scientific cooperation between both nations with an important role played by the cadre of US-trained Chinese scientists and engineers that took the lead in the knowledge transfer activities. 1949, however, represents a dramatic rupture of the scientific collaborations with the establishment of the People's Republic of China. Under Mao Zedong, official science and technology agreements were interrupted and scientific relations were relegated to non-official scientific relations that persisted between the US and Chinese scholars (Millwood, 2021). During the 1960s, American scholars created the Committee on Scholarly Communications with Mainland China (CSCMC) supported by the National Academy of Science, the American Council of Learned Societies (ACLS), and the Social Science Research Council (SSRC). The CSCMC was an independent and non-official initiative that facilitated the exchange of publications and meetings between the US and Chinese scholars in international conferences and aimed to maintain scientific collaborations despite difficult political relations (Smith, 1998).

It was under the Deng Xiaoping and Jimmy Carter governments in the 1970s that official science and technology cooperation was restored through the signature of the "US-China Inter-governmental Science and Technology Agreement". Through this agreement, a Joint Commission on US-China Cooperation in Science and Technology was created and several programs and sub-agreements were put in place to foster higher research and innovation cooperation and most importantly opened the space for more Chinese graduate students in the US (Smith, 1998).

While on the political and diplomatic side, Sino-American relations have faced ups and downs since the 1980s (Niu, 2010), scientific cooperation has yielded significant results in various fields. In the last four decades cooperation achievements include a Remote Sensing Satellite Ground Station, the Beijing Electron-Positron Collider, the China Digital Seismograph Network, second-generation internet technology, as well as advancements in high-energy and nuclear physics, magnetic confinement fission, surface water hydrology, electric car, and fuel cell vehicle technology development, advanced reactor technology, and most recently, useful progress in agricultural S&T, clean energy, bio-medicine, wireless communication technology, and more (Suttmeier, 2014).

Scientific cooperation in a knowledge economy faces challenges in terms of disputes over intellectual property rights, patents, information security, export control restrictions, and trade barriers, among others (Stiglitz, 1999). In many cases, governmental policies centered on protecting national interests end up hindering and threatening scientific collaboration. However, it is precisely science diplomacy strategies and tools that nevertheless allow for scientific cooperation to advance and influence not only local and national policy, but also influence the international arena.

Science diplomacy

Science Diplomacy is a growing field both in academia and in practice that focuses on the relationship between formal international relations and scientific cooperation. Although this term has been recently used officially by diplomats and scientists, examples of science diplomacy programs have been documented extensively since the Cold War (Turchetti, 2020). The difference between this concept and the independent scientist cooperation approach is the intention that governments may have when fostering programs that use scientific knowledge as the base of diplomatic relations and to promote national interest (The Royal Society, 2010).

There is not a universal consensus on the definition of science diplomacy. However, the initial attempt to define it was in 2009 by the Royal Society and the American Association for the Advancement of Science (AAAS) in the framework of a two-day meeting on science diplomacy. In their published report, three main dimensions of Science Diplomacy are established, namely, *science in diplomacy* (giving scientific advice for foreign policy decisions), *science for diplomacy* (relying on scientific cooperation to advance international relations purposes among countries), and, *diplomacy for science* (developing international programs to foster scientific cooperation) (The Royal Society, 2010).

Much research has been carried out on different scientific programs and strategies to advise on foreign policy (science in diplomacy). Historical studies have documented the long-standing scientific efforts and influence on international ocean policy (Robinson, 2020). Other studies have researched the evolution of global environmental programs led by scientists around the world (Rispoli and Olšákov, 2020). A contrasting example is the case of the Intergovernmental Panel on Climate Change that despite having a weak impact in terms of diplomatic decisions and governments commitment, it has been a positive international effort that provides sound scientific evidence for policies on climate change (Ruffini, 2018), in addition to significantly galvanizing global scientific consensus and popular opinion.

Likewise, the use of science in contexts of tense international relations has been documented extensively. Historical studies have shown the pivotal role that science collaborations played in the aftermath of World War II as a peace-building tool (Miller, 2006). The important role of scientific collaboration in avoiding a latent nuclear conflict during the Cold War has inspired many authors in analyzing science for diplomacy mechanisms (Barth, 2006; Turchetti, 2020).

Diplomacy for science, in contrast, has been a field of less research and attention (Linkov et al., 2016). Some studies have focused more on the role that science diplomats play to acquire information regarding the host nation's scientific priorities and the responsibility to foster research collaborations programs that support national interests (Linkov et al., 2014). Some initiatives that have resulted from diplomacy for science policies are the creation of binational science and innovation centers. These centers require the efforts and collaboration of universities, research institutes, think tanks, innovation organizations, and public institutions. The cases and best practices from Germany and Switzerland shed light on the positive impact of these efforts (Epping, 2020). Other types of analysis found are the impact assessment reports of international research collaboration programs. For example, the United Kingdom's Newton Fund program has produced several evaluation reports for different countries. For the China-UK program, the assessment was carried out through case studies documenting the results of research collaboration programs in precision agriculture, breast cancer innovative therapy, and climate science for service partnership (Department for Business, Energy, and Industrial Strategy, 2022).

The global and common environmental threats that the world faces underline the importance of science diplomacy. Particularly, the constraints, shortages, and scarcity of food, water, and energy as a consequence of climate change, were recognized at the Royal Society and AAAS conference in 2009 (The Royal Society, 2010). Indeed, some of the earliest programmatic development of "nexus" interlinkages between food and energy (Scott et al., 2015) were pioneered by the United Nations University, arguably a science for diplomacy institution of the international community. The Water, Energy, and Food nexus has become a field of special interest for science diplomacy programs and initiatives for many of the above-mentioned reasons. Our intent here is not to review the Nexus framework but to introduce those elements that are particularly salient to the science diplomacy focus of the present *Frontiers* special issue.

The FEW nexus framework

Definitions and theoretical frameworks of the FEW Nexus are contested and this is a field in constant development. Insights on the coupled linkages between the three systems include not only the nexus assessment of resource quantification but also resource management and policy.

In a comprehensive review Albrecht et al. (2018) analyzed more than 245 papers that have been published under the FEW Nexus approach. However, they point out that much of the research carried out does not integrate appropriately the analysis of the interdependencies between the three systems. In addition, they identify that many studies are water-centered and carry out assessments of the interdependencies of just two systems. From the overall review, just 18 papers represent best practices in the implementation of interdisciplinary, participative, and mixed (qualitative and quantitative) research methods.

Some authors introduce a nexus framework centered on resource recovery as a fundamental biophysical expression to diminish the human footprint on planetary boundaries (Scott et al., 2015). This framework analyzes the interlinkages of the FEW Nexus on three planes, namely, biophysical resources, institutions, and security. Going further, some other authors focused on understanding the integration through three alternative perspectives, including incorporation, cross-linking, and assimilation (Al-Saidi and Elagib, 2017).

Modeling frameworks have been also introduced to assess FEW Nexus interlinkages. Some examples are the Multi-Scale Integrated Assessment of Societal Metabolism (MuSIASEM) which focuses its analysis on the metabolic patterns of socio-ecological systems counting for different hierarchical levels, scales, and dimensions of analysis (Giampietro and Mayumi, 2000; Pérez-Sánchez et al., 2019). A *FEW Nexus tool* has been introduced based on the analysis of the flows and interconnections between the three systems taking into account inputs and outputs of an integrated system allowing for modeling of different scenarios (Daher and Mohtar, 2015; Daher et al., 2017). Laspidou et al. (2020) introduced the *Nexus_SDM* as a systems dynamics tool with visualization to highlight WEF interlinkages.

The NSF considers the Nexus to be an example of its "10 Big Ideas" in its call for "Convergence Research." As a result, we conjecture that the FEW Nexus is more amenable to science diplomacy collaboration than, for example, purely physical science programs.

InFEWS US-China program

The US NSF InFEWS program was created in 2016 with the following three main goals: (a) support integrated experimental research toward creating a comprehensive food-energy-water sociotechnical systems model; (b) advance knowledge/technologies that foster safer, more secure, and more efficient use of resources within the food-energy-water nexus; and (c) support an integrated approach to building the next-generation INFEWS workforce. According to the NSF program webpage, 96 projects have received funding with a total allocated amount of US$ 167,569,869.

In 2018, a joint program with the Chinese NSFC was launched to promote collaborations between the US and Chinese scholars and researchers to advance in the Food, Energy, and Water Nexus.[1] Specifically, InFEWS US-China called for

1 Links to NSF InFEWS US-China calls:
2018: https://www.nsf.gov/pubs/2018/nsf18096/nsf18096.jsp.
2019: https://www.nsf.gov/pubs/2020/nsf20019/nsf20019.jsp.
2020: https://www.nano.gov/node/2890.
2021: https://www.nsf.gov/pubs/2021/nsf21103/nsf21103.jsp?WT.mc_id=USNSF_25&WT.mc_ev=click.

proposals on the themes of (1) Quantitative and computational modeling of a Food, Energy, and Water (FEW) System, and (2) Innovative human and technological solutions to critical FEW systems problems. The program requested research proposals to be submitted by research teams in both countries to their corresponding agencies, namely, US scholars to the NSF and Chinese scholars to the NSFC. The funding provided to winning proposals by each agency was on average US$500,000 for projects to be implemented for up to 4 years. The program terms of reference established the condition to include the participation of researchers from at least one US institution and at least one institution in China.

Between 2018 and 2021 20 projects totaling $8 million were granted by the NSF to US research teams. Although public information is not available, this means that the same number of projects must have received funding on the China side. According to publicly available data on the NSF webpage, the winning teams on the US side have reported the publication of 47 research papers funded under the INFEWS US-China program. This information was not accessible from the NSFC webpage.

Data and methods

This paper carries out a descriptive analysis on three levels. The first focuses on assessing the research collaborations patterns and the role of the Chinese scientific diaspora in the InFEWS US-China program as an example of the impact of a diplomacy for science mechanism. The second centers on determining if the research proposals awarded by the NSF show a clear understanding of the FEW Nexus by incorporating the interlinkages of the three systems in the abstracts of the winning projects. Finally, a review of all the research papers reported to the NSF under the program is carried out focusing on the use of the FEW Nexus concept.

A first dataset was downloaded from the NSF webpage with the report of all the grants awarded for the InFEWS US-China program. This dataset was filtered to identify all the grants awarded under the US-China program. Next, each project was searched on the web under its award code to access the summary report of each project on the NSF webpage. This provided information about the leading institution in the US, the partner institution in China, the principal investigator (PI), the abstract of the full proposal, and links to all the self-reported publications from each project. This dataset was complemented by searching on the web for each PI to identify the institution where they obtained their bachelor's degree under the reasoning that if authors studied as undergraduates in a Chinese university, they are likely Chinese. In addition, information about their gender and institutions of graduation from all levels were codified. Lastly, each project was classified on either of the two program themes (1. Computational modeling or 2. Technology innovation) by extracting the information from the abstracts.

The second level of data analysis was carried out using SCOPUS to search for and create a list of each reported publication. Of the 47 publications reported, 7 papers were not found in SCOPUS. All the bibliometric information, including title, authors' names, institutional affiliations, keywords by authors, abstract, citations index, and funding sources were downloaded to an excel file. The operational analysis of this data is shown in Table 1.

Consequently, the sample covered in this review includes all the winning proposals awarded by NSF as well as the corresponding self-reported publications associated with each project. A summary of the winning proposals identifying the US institutions and their corresponding Chinese partner institutions is shown in Table 2. Information is reported also on the amount granted in dollars and the papers reported to NSF as a result of the grant.

Analysis and discussion of findings

Collaboration patterns

Chinese diaspora organizations and its collaborations patterns with scholars in their homeland have been portrayed as a best practice. Some reasons for this success rely on the high number of Chinese scholars that leave overseas (over a million), their capacity to create more than 200 diaspora organizations, and the intentional policies at the federal and provincial levels (Meyer, 2011). The social capital theory has been used to explain the success of this fluid scientific collaboration stressing the importance of language and cultural understanding that facilitates and enables successful scientific collaborations (Biao, 2005). In the case of the InFEWS US-China program, 65 percent of the PI's (13 in total) did their bachelor's degrees in China (see Table 3). Six projects led by these Chinese scholars have published with Chinese co-authors affiliated with institutions in China. This represents an initial understanding of how the social capital and networks of Chinese scholars function under the InFEWS diplomacy for science mechanism.

As shown in Figure 1, Nanjing Agricultural University stands out as the main Chinese partner institution collaborating with 6 out of the 20 winning proposals. This university is recognized worldwide as a leading research institution in agricultural, plant, animal, and environmental science according to the World University Ranking[2] and is placed number 135 in the Best Global Universities.[3] Its internationalization

2 https://www.timeshighereducation.com/world-university-rankings/nanjing-agricultural-university

3 https://www.usnews.com/education/best-global-universities/nanjing-university-503849#summary

TABLE 1 Operationalization of data.

Operationalization method

Source of data	Unit of analysis	Analysis
NSF proposal summary information	Principal investigator's (PI's) undergraduate institution	Does the PI have a Chinese background? Are the Chinese researchers collaborating with the institutions they graduated from?
	Abstract analysis	To what theme does the project respond? Does the project abstract establish a clear interlinkage of the three FEW Nexus systems?
SCOPUS publication bibliometrics	No. of co-authors	Patterns of collaboration
	Is the PI of the NSF project co-author of the publications and in what authorship position	Is the research project led exclusively by the PI or are there emerging scholars in the field?
	Is the publication co-authored with scholars from the Chinese partner institutions	is there evidence of a real binational research collaboration?

strategy and research network include over 150 partnerships and agreements around the globe and has been taking part in large international research projects with the European Union, the US, and United Nations Programs reported by World University Ranking. The universities of Dalian and Harbin Institute of Technology each have two partnerships under the InFEWS program. No Chinese institution partner was found for four of the projects listed.

Specifically analyzing the bibliometric information from all the 40 publications under review the average number of co-authors is 8.5 with a minimum number of authors of 2 and a maximum of 57. Thirty-one of the 40 publications listed the PI of the NSF project as co-author, but not necessarily as first author (which was the case for just five papers). This may be evidence that PI's are promoting the engagement of young scholars. Finally, 21 publications have scholars affiliated with institutions in both countries. However, just 10 of these 40 publications are co-authored with scholars from the official Chinese partner institution.

FEW nexus assessment in NSF InFEWS US-China proposal abstracts

The analysis carried out in this section is based on the abstracts of the 11 projects that have reported publications and were found in SCOPUS. Of the total, six proposals respond to computational modeling challenges, three tackle technology innovations and three address both themes.

All the proposals from the computational theme establish a clear interlinkage between the three FEW systems. Every abstract mentions individually each of the systems of the FEW and establishes a clear relationship between them. The computational models proposed in some cases rely on models developed for each of the systems but propose bridges between these models (Award No. 1804560 and 1805808). Two projects propose to carry out comparative FEW Nexus analysis on specific locations in both countries (Award No. 1903722: Mississippi River Basin and Yellow River Basin, 1903249: Yellow River Basin). An innovative study integrates wave energy-based seawater desalinization systems, sustainable reclamation of saline-sodic alkaline soils, and a nexus of ocean energy, freshwater, and coastal agriculture (Award No. 1903627).

In contrast, none of the three projects presented under the technological innovation theme demonstrates a clear understanding of the interdependencies of the FEW Nexus. Award No. 1803200 focused on electrocatalyst for CO_2 conversion using electrochemical processes. They do test some renewable energies in the process but the link between water and food is not clear. Award No. 1903597 proposes a biological active filtration system to purify water resulting from rice crops. The nexus between water and food is clear in this case, however, energy is not incorporated. Lastly, Award No. 1903705 focuses on its analysis of integrated treatment for source-separated urine. Although they point out the importance of the resulting finding for nitrogen and phosphorous recovery that may be essential for agriculture production, they do not highlight this connection, nor do they establish a relationship with the energy system.

The remaining two projects addressing both themes show a clear understanding and evidence of the interdependencies of the FEW Nexus in their proposals. Award 1804453 is focused on modeling and developing technology to carry out hydrothermal liquefaction techniques for the conversion of wet biowaste and algae into biocrude. Award 1804453 models the impact on how petroleum products impact the development and growth of oysters due to the changing quality of water.

This analysis shows that on the computational modeling proposals there is a clear understanding

TABLE 2 InFEWS US-China projects funded by NSF (information extracted through the NSF webpage).

US Institution	Chinese Partner Institution	Awarded Amount (US$)	Publications
Purdue University	Center for Energy and Environmental Policy, State Key Laboratory, and Center for Chinese Agricultural Policy	$499,341.00	2
University of Illinois at Urbana-Champaign	China Agricultural University	$500,000.00	5
Louisiana State University	Dalian Ocean University	$291,788.00	1
Texas A&M University Corpus Christi	Dalian Ocean University	$208,087.00	0
Vanderbilt University	Harbin Institute of Technology	$177,914.00	0
Columbia University	Harbin Institute of Technology	$364,710.00	1
University of Missouri-Columbia	Jiangnan University in China	$500,000.00	0
University of Utah	Nanjing Agricultural University	$149,845.00	1
University of South Carolina at Columbia	Nanjing Agricultural University	$199,942.00	0
California State University-Fresno Foundation	Nanjing Agricultural University	$149,818.00	0
Virginia Polytechnic Institute and State University	Nanjing Agricultural University, and Wuhan University of Technology in China	$500,000.00	3
University of Tennessee Knoxville	Nanjing Agriculture University	$500,000.00	0
University of Maryland, College Park	Nanjing Hydraulic Research Institute, Chinese Academy of Sciences, and the Northwest Agriculture and Forestry University.	$500,000.00	6
Lehigh University	Not Reported	$499,891.00	3
Auburn University	Not Reported	$500,000.00	13
University of Maryland Center	Not Reported	$500,000.00	2
North Carolina State University	Not Reported	$500,000.00	0
University of Delaware	Tianjin University	$500,000.00	7
West Virginia University Research Corporation	Zhejiang Sci-tech University	$494,888.00	1
New Jersey Institute of Technology	Zhejiang University	$500,000.00	2
Total		**$8,036,224.00**	**47**

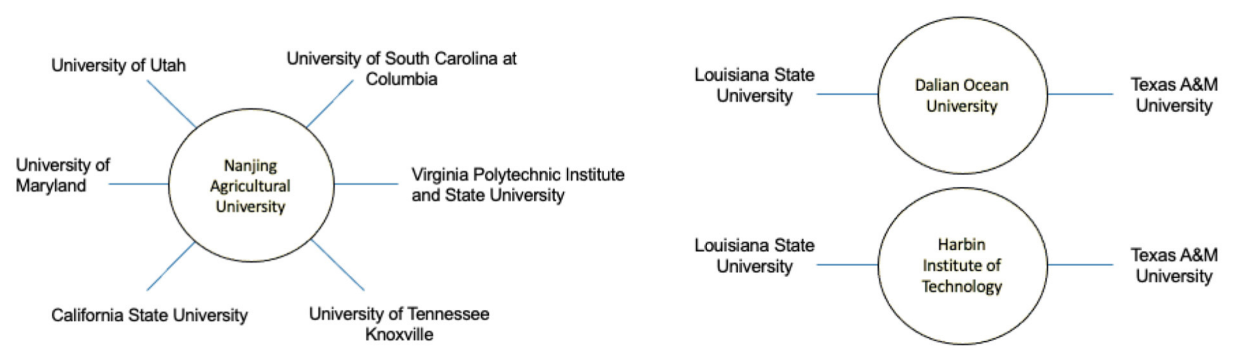

FIGURE 1
InFEWS US-China collaboration networks of selected Chinese universities.

of the FEW interdependencies, although few if any projects addressed the policy implications of their work either in site-specific resource management terms or, for the interests of this paper, for science diplomacy. None of this was the case for the technological innovations projects that may be focused on tackling very particular issues that do not manage span the FEW Nexus interlinkages.

Review of the research output reported to NSF

This section will follow the same structure as the previous one by considering InFEWS US-China program themes. When filtering by keywords the computational modeling projects none of the 25 publications includes the word "nexus", four include the word "water", three the word "energy", and one the word "food". If trying to look for alternative ways to search for a coupled approach five papers are found with the word "climate". From the water-centered publications, one establishes a water-energy nexus by analyzing the effects of climate change on the hydroecological conditions and natural hazard risk (Yang et al., 2019). Another publication establishes a water-food nexus by analyzing the effects of conservation tillage used in corn-soybean on crop water productivity (Huang et al., 2021). Publications from this research project (Auburn University) are related either to nitrous oxide quantification (Tian et al., 2020a,b; Yao et al., 2020; Bian et al., 2021) or to evapotranspiration (Pan et al., 2020). Despite their lack of direct usage of a nexus definition, their findings contribute solidly to the FEW Nexus field.

The energy papers are mostly centered in their own unique field (Ogunrinde et al., 2018; Mi et al., 2020), with exception of one paper that analyzes the moist heat stress on farmers' productivity (Buzan and Huber, 2020). The University of Maryland makes significant contributions through six publications focused on precipitation and climate models. Although they do not mention the nexus approach, their findings are pivotal to assessing models that incorporate the effects of climate change in accounting for changing patterns of precipitation for agriculture and hydroelectric energy (Sun and Liang, 2020a,b; Sun et al., 2020; Li et al., 2021). It is important to highlight that almost all publications from this are co-authored by researchers from their partner, Nanjing Agricultural University, which may result from a project governance policy developed by the U Maryland and Nanjing U team.

On the technological innovation theme, there are nine publications in total but just one publication is co-authored by scholars from both countries. The partnership between the University of Delaware and Tianjin University contributes six publications reporting mainly on their advancement in the electrochemical conversion of CO_2 methods and technologies (Jouny et al., 2019; Luc et al., 2019; Ko et al., 2020; Xia et al., 2020). The remaining publications introduce the technology of using biochar to purify water (Liu et al., 2021) and an isothermal membrane distillation with an acidic collector for the recovery of ammonia from urine (McCartney et al., 2020).

Finally, of the projects that tackle both themes, one is led by Louisiana State University with a paper that analyzes the Mississippi River discharge impact on the Barataria estuary salinity and its effects on marine life (Ou et al., 2020). The other one is carried out between the University of Illinois and China Agricultural University with all binational publications, again possibly reflecting specific project governance agreements between the PIs. The five publications from this partnership are focused on progressing in refining the techniques for biocrude production using hydrothermal liquefaction methods. This project shows different experiments that they have done using different types of livestock and techniques (Stablein et al., 2020; Watson et al., 2021a,b). One of the most interesting projects carried out is the one where they use food waste from a university campus and combine it with wastewater to produce biocrude (Aierzhati et al., 2021). Their research is pushing the boundaries not only in technological innovation but also in quantifying its economic viability (Watson et al., 2020) and at the same time expanding the boundaries of FEW Nexus research and applications.

TABLE 3 Nationality of principal investigators.

China	USA	Taiwan	India	Singapore
13	4	1	1	1

This study has several limitations that we consider to be avenues for future research. First, the lack of information on NSFC-approved projects, either in relation to resources allocated, partnerships, institutions, or PI's, impedes a complete picture of InFEWS US-China. In addition, as none of the projects has completed implementation such that the final outcomes are not yet available, our review covers work in progress and should not be taken as a comprehensive analysis of the potential contributions of the program to advancing the FEW Nexus framework, given that many of the projects may be in the middle of their implementation process. Additionally, in terms of methods, the collaboration patterns can be systematically and more reliably carried out using network analysis tools (e.g., see Dennis and Grady, 2022) that would allow an analysis not only of the project PI's but also a full network analysis of the co-authors to identify previous patterns of collaboration that may explain the degree of success of certain institutional partnerships. Finally, an interactive survey of InFEWS US-China project team members, particularly concerning their assessment of science diplomacy objectives, would provide unique insights to both expand and solidify science diplomacy as well as to expand global understanding of the FEW Nexus.

Conclusion

The InFEWS US-China program is a clear example of diplomacy for science. The collaboration patterns show that scientific advancement in the field of climate change requires collective efforts indicated by a high average number of co-authors per paper. These collaborations in many cases are stronger when incorporating different perspectives, contexts, and cultural backgrounds. Therefore, promoting and enhancing major international collaborations through diplomacy for science programs is a needed strategy that should be incorporated within all countries' international relations policies. Nanjing Agricultural University emerged as the leading partner institution in China. This paper does not show evidence of a specific reason for this to occur, however, the long-standing international relations by this institution may explain a global engagement culture not common in many Chinese universities.

In terms of the FEW Nexus advancement, it is clear that the framework is well incorporated within the NSF proposals by establishing in most cases clear interlinkages among the three systems. However, the research output does not support a clear appropriation of the concept by the research teams. Although much of the research findings may make significant contributions to FEW Nexus analysis, many of the research outputs do not incorporate the FEW Nexus within its explanatory frameworks or conclusions. Finally, few if any projects explicitly considered the broader policy implications of their research (for FEW management, climate change adaptation or mitigation, sustainable development, or human security).

Despite the Trump Administration publicly promoting anti-climate change policies and carrying out confrontational diplomatic relations against China, the InFEWS US-China program maintained and extended scientific collaborations between US-based and Chinese scholars in the fields of climate change and sustainable resource management. As demonstrated above, there is an important role played by the Chinese scientific diaspora leading 65 percent of the winning InFEWS US-China proposals. The social capital theory has been used to explain the success of these dynamic scientific collaborations stressing the importance of language and cultural understanding that facilitates and enables successful scientific collaborations (Biao, 2005). Although we were only indirectly able to address the role or willingness of the Chinese scientific diaspora in the US in moderating the confrontational "*America First*" diplomatic context in which InFEWS research was initiated, it is evident that multiple binational teams have conducted, and continue to develop successful science policy research. Furthermore, the strength and cohesion of the Chinese scientific diaspora and the policies promoted by the Chinese government may serve as inspirations to diaspora networks from other countries to strategically contribute to their homeland while living abroad (Shin and Moon, 2018).

This program shows evidence of the important role played by the Chinese scientific diasporas in developing research collaborations with their home countries. This may serve as a good example of the transforming concept of Brain Drain into Brain Circulation (Fangmeng, 2016). Governments may use this case as source of inspiration to design policies that incorporate not only incentives for high skilled scientist to go back to their home countries, but also develop incentives for those scientists that want to stay abroad and build networks with their local higher education system.

Author contributions

JP and CS contributed to conception and design of the study. JP created the NSF InFEWS database and wrote the first draft of the manuscript. CS revised and made improvements on the first draft. Both authors contributed to manuscript revision, read, and approved the submitted version.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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Voices of the Costa Rican scientific diaspora: Policy lessons from a decade of experiences from our scientists abroad

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Scientific diasporas have been identified as valuable resources to strengthen science, technology, and innovation in their countries of origin. In this context, our paper seeks to contribute by addressing the following research questions: What are the main features of the Costa Rican scientific diaspora, and what policy lessons can be extracted from their experiences abroad? Toward this goal, we analyzed ten years of diaspora perspectives as collected by TicoTal, an online database and network of Costa Rican scientists studying and working abroad created by the National Academy of Sciences (ANC) in 2010. Our study reveals the main features of the Costa Rican scientific diaspora using 121 interviews published over a ten-year period: we identified the academic areas in which the diaspora has specialized, the countries where they were trained, their current location, the most frequent funding mechanisms and sources that enabled professional opportunities abroad, the level of engagement and collaboration they maintain with the Costa Rican STI ecosystem, along with the incentives they consider important to support and harness the potential of this community to advance STI goals in the country. Results from this analysis can inform national policies and investment strategies in R&D infrastructure and resources, by providing a roadmap to engage with scientific diasporas and benefit from their training and talent, as well as guide future scholarship and exchange programs.

KEYWORDS

scientific diasporas, science diplomacy, Costa Rica, Latin America, research and development (R&D), higher education institutions, policy and investment strategies

Introduction

The migration of human capital from low-income countries to higher-income economies (known as "brain drain") has been shown to affect the local consolidation of science, technology, and innovation (STI) in low and mid-income countries and can have significant impacts in specific fields (Meyer and Brown-Luthango, 1999; Commander et al., 2004; Giannoccolo, 2009; Kim et al., 2013; Vega-Muñoz et al., 2021). More recently, 'scientific diasporas', defined as highly qualified human capital temporarily or permanently residing outside of their home countries, have been identified as a valuable resource to strengthen STI in their countries of origin (World Bank Institute, 2006). Indeed, the landscape of migration of talent has been described as one of 'brain circulation', offering new possibilities to mobilize scientific diasporas as dynamic engines in support of the development of STI (Kuznetsov and Sabel, 2006; Tejada, 2007; Docquier and Rapoport, 2012; Siekierski et al., 2018; Shin and Moon, 2018; Organización Internacional para las Migraciones [OIM], 2019; Biglari et al., 2022). In this context, understanding the characteristics of scientific diasporas is imperative to strengthening national STI goals and programs.

Within this frame of reference, our paper seeks to contribute by addressing the following research questions: What are the main features of the Costa Rican scientific diaspora, and what policy lessons can be extracted from their experiences abroad? Toward this goal, we analyzed 10 years of diaspora perspectives as collected by TicoTal[1], an online database and network of Costa Rican scientists studying and working abroad.

TicoTal[2] (*Red de Talento Costarricense en el Extranjero*; Network of Costa Rican Talent Abroad) was created by the National Academy of Sciences (ANC) in 2010. This database compiles information from Costa Rican scientists and engineers who study or work abroad either permanently or temporarily. The main goal of TicoTal is to connect this diaspora with the Costa Rican STI establishment in order to foster alliances and cooperation that can strengthen and advance STI goals in the country.

Every month, ANC publishes an interview with a member of the TicoTal network, which is shared publicly *via* a listserv with all subscribers. Each interview covers the interviewee's pathway to STI opportunities abroad and highlights key challenges faced, incentives they value in the consideration to return or to collaborate with Costa Rican-based STI stakeholders, as well as perceived needs to bolster STI in the country.

A second platform that quantitatively tracks the Costa Rican scientific diaspora is *Hipatia*[3], hosting a series of surveys, data analysis, and services covering the country's STI needs. Every year, *Hipatia* carries out a comprehensive and systematic mapping of the scientific diaspora. This resource contributes particularly by facilitating contact between Costa Ricans abroad and local startups so that they receive mentoring in different areas of expertise.

While these resources collect and maintain up-to-date information on Costa Rican scientists abroad, experts have emphasized the importance of analyzing the perspectives of scientific diasporas when designing policies of interest to these populations (Séguin et al., 2006; World Bank Institute, 2006). With this goal in mind, our paper consolidates the explicit perspectives of the Costa Rican scientific diaspora and carries out - for the first time—a mixed methods approach (systematic quantitative and qualitative analysis) of 10 years of interviews published by TicoTal between 2011 and 2021.

In the following sections, we analyze the academic areas in which the diaspora has specialized, the countries where they were trained, their current location, the most frequent funding mechanisms and sources that enabled professional opportunities abroad, the level of engagement and collaboration they maintain with the Costa Rican STI ecosystem, along with the incentives they consider important to support and harness the potential of this community to advance STI goals in Costa Rica. Lastly, we propose recommendations on how to generate engagement with an STI diaspora, in a way that positions members as key agents who favor the scientific and technological development of their home country.

Methods

Our paper addresses the following research questions: What are the main features of the Costa Rican scientific diaspora and what policy lessons can be extracted from their experiences abroad? The main sources of analysis are the interviews "Talento Destacado" (hereafter called "Outstanding Talent") published as part of the monthly ANC newsletter, with the purpose of highlighting Costa Rican students and researchers in STI fields who are living abroad. Their personal motivations and challenges, research interests, disposition, or preconditions to return home, and professional recommendations for Costa Rica to advance STI are valuable sources of information and encouragement for other young Costa Ricans who also wish to seek opportunities to study or work abroad. In addition, this platform also serves as a tool for members to connect among

1 It can be accessed *via* the following link: http://ticotal.cr/conozca-acerca-de-ticotal.html.

2 At present, the TicoTal network has 556 members (who will be referred to here as "TicoTales"): 380 men and 176 women, who are distributed across 31 countries. Of them, 282 TicoTales reside in the American continent, 247 in Europe, 14 in Oceania, 12 in Asia and one in Africa. They are all active postgraduate students or professionals in STI fields, such as engineering, technology, agricultural, natural, and medical sciences.

3 It can be accessed *via* the following link: https://hipatia.cr/.

themselves across different parts of the world, learn about each other's research projects, and establish collaborative efforts.

The selection of the featured "Outstanding Talent" individuals is made by the ANC staff following no specified criteria, although gender equity is sought by alternating profiles from men and women. A sample of interviews was selected for this analysis, encompassing 121 interviews published in the newsletters between December 2011 and December 2021. The eight survey questions remained consistent across the decade covered by the analysis for all interviewees.[4] Answers from interviewees were not word-limited and were not edited by ANC personnel prior to publication in the newsletter. This feature of survey consistency allowed for a systematic characterization of the diaspora.

The work of systematically reviewing these eight answers from 121 interviewees was divided among three of the coauthors (MEJS, ELS, and KCZ), who codified 62 variables out of these responses into a database. Variables were grouped into four main domains related to an interviewee: (a) identity and background, (b) funding conditions, (c) contact with Costa Rica, and (d) incentives to return and challenges abroad.

The first domain covers variables such as name, gender, month of the interview publication, and STI area of research, which can be chosen from a predetermined menu of options. Additionally, we extracted what undergraduate degree they reported and from which university it was obtained, as well as which country it is located in. We also codified if they reported having a Master's, a Ph.D., and/or a postdoctoral position (as binary variables), and the universities and countries each of these occurred in.

Identity and background variables were set on two temporal frames of reference: (i) the moment of the interview (recognizing there may be a 10-year time span between when this took place for different individuals) and (ii) the present, when the analysis is being performed (fixed as February 2022). Most identity and background variables are taken as reported at the moment of the interview. The few variables fixed in the present were extracted from other public sources, such as the interviewees' LinkedIn profile or their academic department's website. These updated variables include their current job position, the organization where they work, and the country of residence at present. Based on their full name, their birth date was extracted from the public database of the Costa Rican National Registry (Tribunal Supremo de Elecciones [TSE], 2022), in order to compute their exact age at the moment of the interview.

The second dimension of variables logs whether the individual's studies were financed through foreign, national (that is, Costa Rican) or personal funds, or a combination of these sources. Another variable related to funding codified if the financial sources were public or private money or a mix of the two. Finally, two variables registered whether the person reported having been part of an exchange or internship program abroad (binary variable), and the detail of how it served as a mechanism to enable the continuation of their studies.

Variables in the third grouping report if the person maintains contact with various sectors in Costa Rica, among them academia, industry, decision-makers, and colleagues in the diaspora (as binary variables). In the event that contact is reported, the detailed means of engagement is noted as an open, non-codified variable. This category also documents if the person is willing to establish a collaborative effort with Costa Rica (binary variable) and the details of that offering, for example hosting visiting students.

The final collection of variables registers the types of incentives the interviewees listed (as binary variables) as a precondition to returning to Costa Rica. They are grouped into three types:

- Infrastructure (relating to new research centers, equipment, access to information databases, salaries, or overall budgets).
- Networks (relating to training opportunities, scientific events, scientific collaborations, or positioning of science).
- Cultural (relating to the socio-economic and cultural conditions, other job opportunities or the role of science).

Open variables about the specific incentives requested from each category were annotated. Finally, there is a variable that registers, in a non-codified format, the challenges reported by the individual while abroad.

Given the relatively open frame of the interview questions, which in most cases do not specifically inquire about our target variables, we relied on the interviewees having directly reported each variable. The absence of a variable may simply reflect the failure of the person to document it in their answer, imposing a significant source of uncertainty on our analysis. Variables were not exclusively extracted out of predetermined questions, but in general variables about identity, background and funding were mentioned in the answers to questions 1. and 2., variables about contact with Costa Rica were predominantly inserted in answers 2. through 7., and variables about incentives were contained in answers 5. through 8.

It is also recognized that this study, by the original design of the raw dataset, is limited in scope to the Costa Rican

4 The interview included the following questions: (i) What were the determining factors in and/or opportunities to go abroad?, (ii) In general terms, how would you describe your living conditions abroad?, (iii) What type and intensity of professional contact do you have with CR?, (iv) Recommendations of initiatives that support talent abroad to act as agents of development in Science and Technology, (v) Would you be willing to return to the country if the right possibilities arise?, (vi) What incentives do you consider pertinent to retain scientific talent in the country?, (vii) In your area of work, what would be the development needs of the area in CR? and (viii) Would you like to make any additional comments?

scientific diaspora, which is defined as individuals who are studying and researching in areas from the natural and hard science fields. We acknowledge a significant gap in tracing and documenting valuable insights from the Costa Rican diaspora that work and study in the fields of social sciences, humanities, and arts. Furthermore, certain sample biases are implicit by way of the process through which the TicoTal network is generated. ANC relies in large part on mechanisms such as word of mouth, friends of friends, and media visibility to recruit new TicoTal members, biasing the pool of people from which the "Outstanding Talent" profile is then "hand-picked," adding yet another bias. Some results presented here, for example, geographical representation may reflect these biases, as ties with certain groups of the diaspora are stronger due to geographical access or cultural proximity. Another limitation is that the data was collected over a 10-year period. It is therefore likely that interviewees may have been impacted by specific events and circumstances at the time of the interview, which may mean significant change between interviews conducted a decade ago compared to more recent ones. This has been addressed in the Results section with an analysis of responses over time.

The database was processed using Excel and R software, in order to compute statistics and trends and to generate the figures presented.

Results and discussion

A historical look at the consolidation of the STI community in Costa Rica

The development of STI in Costa Rica has been characterized by twists and turns since the dawn of its independent life in 1821. The first stages were primarily influenced by foreign naturalists, who studied the rich biodiversity of the country. Then, the appearance of local scientists seeded endogenous efforts in several fields, bolstered by liberal reforms that dominated the political landscape of the country in the last decades of the XIXth century and the beginnings of the XXth century, including the foundation of several research institutions focused on science and technology (Gómez and Savage, 1983; Coronado, 1997; Peraldo-Huertas, 2003; Solano Chaves and Díaz Bolaños, 2005).

A significant breakthrough in the institutional history of Costa Rica took place in 1940, with the creation of the University of Costa Rica (UCR). Besides offering novel opportunities for Costa Ricans to obtain professional degrees, scientific and technological research flourished in this institution in several fields over the next decades (Fallas-Santana et al., 2018). UCR, together with other more recently established public universities, has become the main reservoir of STI development in the country (Lomonte and Ainsworth, 2002; Sáenz-León and Rodríguez-Ramos, 2022).

Parallel key developments included the organization of a governmental framework for the promotion of STI in Costa Rica. The creation of the National Council for Scientific and Technological Research (CONICIT) in 1972 marked a turning point, as part of regional efforts in Latin America promoted by international organizations such as the United Nations Educational, Scientific and Cultural Organization (UNESCO), the Organization of American States (OAS) and the Inter-American Development Bank (IBD) (Sagasti, 2011).

Building on this progress, the Ministry of Science and Technology (currently Ministry of Science, Innovation, Technology and Telecommunications, MICITT) was created in 1986, the National Academy of Sciences (ANC) in 1992, and the Costa Rican Promoter of Innovation and Research in 2021, among other important developments (Fernández-Rojas, 2021). Additionally, the country has established national programs of STI, the last of which was recently issued for the period 2022–2027 (Ministerio de Ciencia, Innovación, Tecnología y Telecomunicaciones, 2021).

The establishment of a local STI community was also enriched by cadres of Costa Ricans who studied abroad in various disciplines and returned to work locally. In the 1950s UCR established an ambitious program of scholarships for graduate programs abroad which contributed to the consolidation of an academic community in this institution.

It is worth noting the example of Leonardo Mata Jiménez, a renowned microbiologist who obtained a Ph.D. at the Harvard School of Public Health and worked for over a decade at the Central America and Panama Institute of Nutrition (INCAP). In 1974, his return to Costa Rica was actively promoted by CONICIT and the UCR. As part of his return, a new research institute (Institute for Research in Health–INISA) was created at UCR in 1975 and Mata Jiménez was appointed as its first Director. He remained in the country for the rest of his career. Similar cases occurred in different areas of knowledge, thus resulting in the creation of different research centers and the strengthening of others.

Despite these developments, the country has significant limitations in incorporating STI as a dynamic element in its social and economic development. A detailed diagnosis of STI in Costa Rica was presented by the "State of the Nation program" in 2014 (Programa Estado de la Nación, 2014). This document highlighted important limitations in this area, such as: (a) low investment in research and development (below 0.4% of the GDP; Ministerio de Ciencia, Innovación, Tecnología y Telecomunicaciones, 2019); (b) limited generation of scientific and technological knowledge, as judged by the number of publications in journals and patents issued to Costa Ricans; (c) scarce links between the scientific and technological community and the broader local social and economic universe; and (d) a small community of researchers, which has problems of redundancy, gender gaps, generational relief, and academic inbreeding.

Given these circumstances, harnessing the potential of the Costa Rican scientific diaspora constitutes an additional opportunity to consolidate a robust STI community in the country (Séguin et al., 2006; World Bank Institute, 2006). The following sections will address the main features of this diaspora and identify policy lessons from their own perceptions and experiences abroad. We further contextualize these perspectives within the framework and recommendations proposed in previous literature on scientific diasporas and international research training.

The Costa Rican scientific diaspora: A snapshot

This section aims to define who and where the Costa Rican scientific diaspora is (as captured by the TicoTal "Outstanding Talent" interviews), particularly what their academic trajectories have been and what funding mechanisms and network resources they used to train abroad. The analysis shows that 53% of interviewees identified as male, and the average age at the time of the interview was 36 years (age range: 23–64). At the moment of the interview, the vast majority (57%) of interviewees had already obtained a Ph.D., 34% were in the process of pursuing doctoral studies and an added 9% held a Master's degree but were not pursuing an additional degree. Notably, 11 individuals departed Costa Rica for STI employment opportunities abroad and did not pursue any further graduate studies.

In terms of STI fields, 41% of the sample were originally trained in basic sciences, 34% in engineering, 20% in health sciences and medicine, and 5% in food sciences at the undergraduate level (Figure 1). However, this image also shows that a subset of the diaspora changed their STI field when moving from their undergraduate level into their current field of work or graduate studies, especially migrating out of engineering to basic sciences, or from basic sciences to health. One hypothesis that might explain these transitions is that the diaspora finds increased flexibility and areas of interdisciplinary work when studying abroad. Further qualitative studies with larger samples should be conducted to confirm this.

We also aimed to answer what proportion of the diaspora returned to Costa Rica over the 10 years covered by our sample. Our data shows that only 23% of interviewees returned by the time of analysis (2022). More specifically, Figure 2 shows that <25% of the diaspora originally trained in basic and health sciences returned to the country. For engineering trainees, the percentage was even lower, with only 15% currently residing in Costa Rica (see flows in green). Together, our findings reveal low return and retention rates across all the STI areas covered by our data. A possible explanation is a lack of support via public policy and mechanisms aimed at attracting the diaspora back to the country.

In contrast, other Latin American governments have deployed official programs to repatriate their diasporas. Two well-known and well-characterized repatriation programs are RAICES (Network of Argentine Researchers and Scientists Abroad) and the CONACyT Repatriation Program in Mexico. Both have been in place for more than 20 years and focus on repatriating scientists, especially in the early stages of their careers, when they are doing their postdoctoral research (Rivero and Trejo-Peña, 2020). Thailand and Poland are also examples of countries that have implemented programs targeting highly qualified expatriates with the aim of encouraging them to transfer part of their scientific activity to their country of origin and promote technological development there (Meyer and Brown-Luthango, 1999; Szkarłat, 2020).

Another finding illustrated in Figure 2 is that half of the diaspora sample living abroad (48%) is currently based in the United States, and the vast majority were originally trained in basic sciences. A significant number of scientists are currently based in Germany, France, the Netherlands, Spain, and England (37%). These percentages are highly concordant with the geographical distribution identified by the *Hipatia* platform, which at the time of this analysis has published data on 759 members of the diaspora. In their dataset[5], 70% of scientists report living in these countries, with the United States displaying the greatest presence (35%), followed by Germany (12%), Spain (8%), The Netherlands (6%), and United Kingdom (5%). France occupies the 7th position (4%), just behind Canada (5%), which is the only country with a limited presence in our sample. Other studies revealed that the Mexican scientific diaspora is also concentrated in these same countries and in Brazil (Marmolejo-Leyva et al., 2015).

Figure 2 also depicts the sector in which this sample is currently training or working. Of the 121 interviewees, 77% are working or continuing their training in academia, and only 23% have transitioned to jobs in the private and public sectors. Notably, while 56% of the interviewees residing abroad work in academia, a small number currently work in foreign public entities such as the National Aeronautics and Space Administration (NASA), the United States Patent and Trademark Office, and the Virgin Islands Department of Health. Additionally, private sector companies in the United States, Germany, and England have hired 21% of the Costa Rican diaspora, which is expected since industry has a high capacity to absorb the abilities that diaspora members offer, according to International Organization for Migration and Migration Policy Institute (2012).

These examples stand in contrast to interviewees who have returned to Costa Rica, as the vast majority work in academia (89%), a single person was identified working in the

5 This data was downloaded in October 2022 and can be found here: https://hipatia.cr/dashboard/diaspora-cientifica.

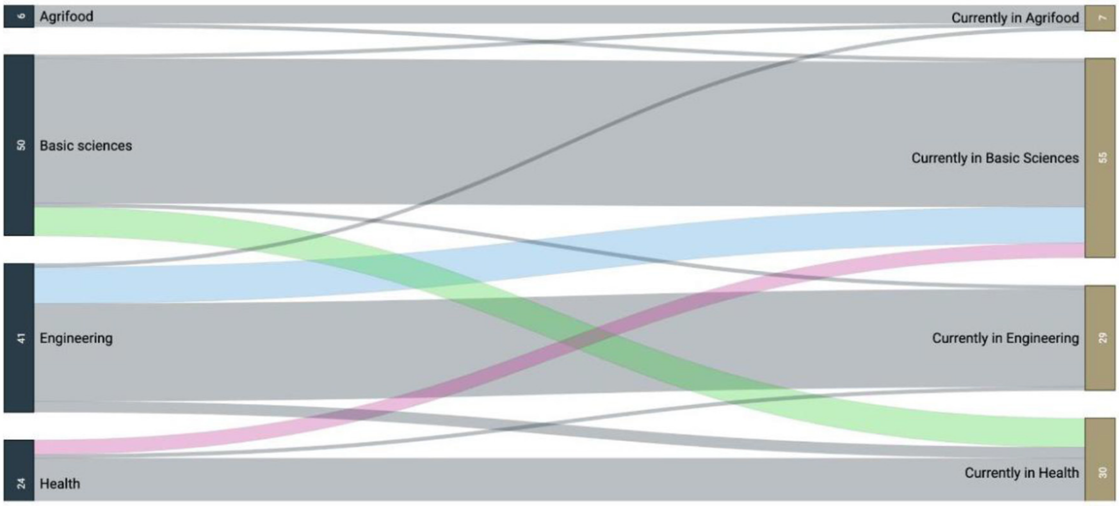

FIGURE 1
STI field of undergraduate studies (left column) and current STI fields in which members of the diaspora are working or training (right column). Numbers on the vertical boxes indicate individuals out of the total sample ($N = 121$).

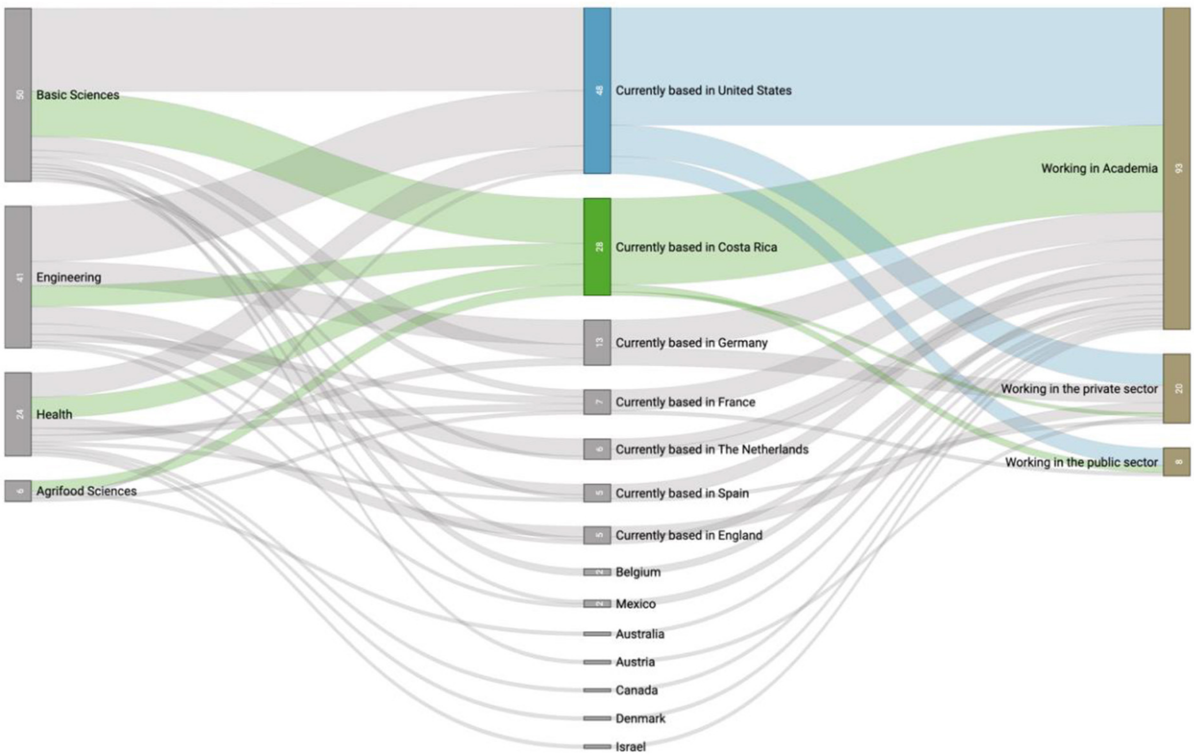

FIGURE 2
Current geographic location (middle column) and employment sector (right column) of the Costa Rican scientific diaspora by academic area (left column). Numbers on the vertical boxes indicate individuals out of the total sample ($N = 121$).

private sector, and two additional people in the public sector (a microbiologist in the national health system and a chemist as Director of Research and Development in the Ministry of Science and Technology at the time of the analysis). Further studies are required to analyze the current efforts by the country's public and private sectors to attract scientific talent from abroad. An example of a national plan that attracted researchers back to civil service and industry was an Argentinian plan, which brought back 178 scientists between 1992 and 1994. Among this group, the largest share joined the private sector (31%), while 15% opted for public administration jobs (Meyer, 2015).

Another goal of our study was to determine in which countries the interviewees pursued their academic degrees and at what point they decided to go abroad. Figure 3 visualizes four academic time points of these 121 scientists: the country where they completed their undergraduate, Master's, and doctoral degrees or conducted postdoctoral training.

Figure 3 shows that the majority of interviewees (89%) obtained their undergraduate degrees in Costa Rica. Of these, only a small number continued their Master's studies within the country followed by a doctorate abroad (see flows in green). Two findings are striking here: (1) no one in this sample pursued their doctoral studies in Costa Rica, and (2) none of those who completed their undergraduate degree abroad returned to the country for graduate degrees. This phenomenon is explained by Dodani and LaPorte (2005), stating that expatriated citizens acquire highly specialized skills which are not frequently taught in their home countries. There is therefore an important challenge for universities: how to retain or attract internationally trained Costa Ricans back to their institutions, either for a graduate degree (Master's or Ph.D.) or to conduct postdoctoral work.

An additional finding of Figure 3 is that regardless of the area of expertise, the majority of people who completed a Ph.D. (82%) and a postdoc (88%) did their training in one of the following five countries: United States (US), Germany, Spain, France, and the Netherlands (see flows in blue). Postdocs are mainly concentrated in the US and Europe, with a single person in Israel. This selection of a subset of countries could be an important guide for decision-makers in academia and government regarding where to deploy bilateral agreements to promote the mobility of Costa Rican scientists abroad; it also highlights where new agreements and collaborations can be improved or increased, to facilitate opportunities in other places.

A noteworthy finding of Figure 3 is that only 37% of the analyzed sample performed postdoctoral work. Significant efforts have been made in the country in recent years to finance postdoctoral fellows, and thus higher numbers of Costa Ricans pursuing postdoctoral training abroad are expected over the next years. Indeed, the UCR financed postdoctoral training abroad for 32 trainees from their institution in the last 5 years (Oficina de Asuntos Internacionales y Cooperación Externa [OAICE], 2022), and a new postdoctoral program was established at UCR just recently.

Another interesting aim of this study was to identify the funding sources used by Costa Ricans to carry out their training abroad. Of the 121 interviewees, 82% indicated that they mainly received financial support from public institutions, both foreign and national, with a large proportion directly funded by stipends provided by foreign public universities (61%)[6].

Of note, 11 people were co-sponsored by public universities of the home and the host country. This could present an important framework to be included in future scientific and international cooperation agreements: The practice of co-financing the training of scientists abroad may in fact be attractive to host universities. Previous studies have shown that -contrary to the so-called "return brain drain"-, once these students return to their countries of origin, they become potential scientific linkages to the host institutions (Jonkers and Tijssen, 2008). In addition, the analysis further revealed that private financing is mainly provided by private universities overseas or direct family support and personal savings. Overall, this highlights little engagement by the private sector in providing and financing academic training opportunities for Costa Ricans abroad.

Lastly, our study sought to identify whether interviewees had used a specific mechanism as a springboard to facilitate their insertion into postgraduate programs abroad. Results show that 23% of people in our sample explicitly indicated having used one. Among the different mechanisms, the most commonly used were research internships (61%), exchange programs (21%), and established or past scientific collaborations between investigators in the home and the destination university (18%). This result is relevant for decision-makers in academia, as it highlights that financing short-term research internships constitutes a platform for students and researchers to obtain additional training opportunities and funding opportunities abroad. For example, the Turkish American Scholars and Scientists Association (TASSA) allocates resources to send students to higher education institutions in the United States to work with diaspora members in specific laboratories (Burns, 2013).

Building bridges: Engagement with the home country and future incentives

This study performed a qualitative analysis regarding the type of social interactions that the interviewed members of the diaspora indicated having with the home country, and specifically with STI stakeholders. This is particularly relevant given that the specialized literature on scientific diasporas has highlighted the importance of creating academic networks between scientists abroad and their country of origin, as well as

6 During fieldwork, it was only possible to locate the funding source for 93 people, which represents 77% of the analyzed sample.

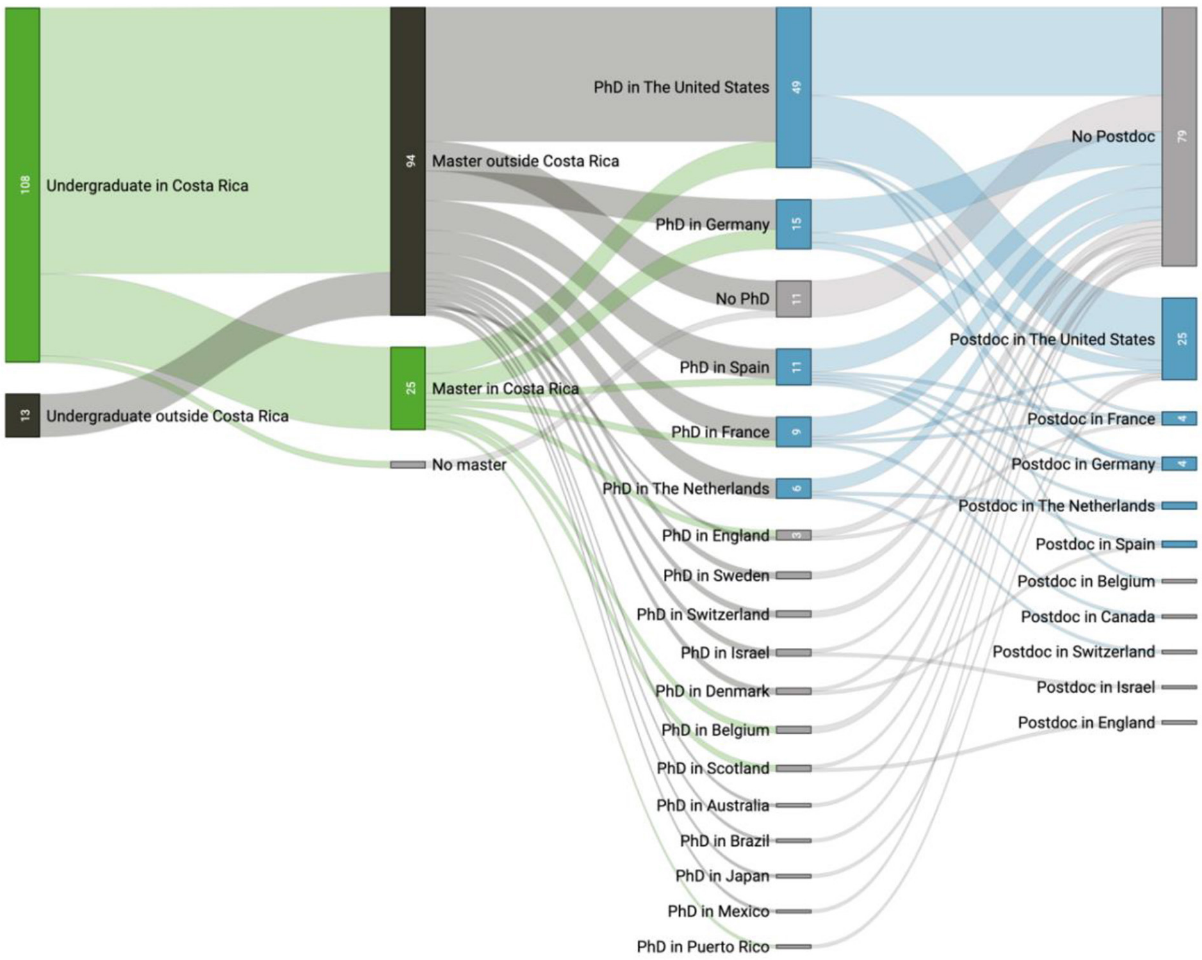

FIGURE 3
Academic pathways of the Costa Rican scientific diaspora: from undergraduate (left column) to postdoc (right column). Numbers on the vertical boxes indicate individuals out of the total sample ($N = 121$).

facilitating platforms where the diaspora can advise decision-makers and advance scientific agreements between the home country and the local ecosystem where they are based (Meyer and Brown-Luthango, 1999; World Bank Institute, 2006; Burns, 2013; Wren, 2018; Ittelson and Mauduit, 2019; Jarquín-Solís, 2022). Among the possible social interactions, our qualitative analysis identified the four STI stakeholders most commonly mentioned in the responses: the local scientific community, government and decision-makers, the private sector, and other members of the diaspora. Figure 4 displays the percentage of members of the diaspora who indicated collaborating with these actors.

As can be seen in Figure 4, the vast majority of the diaspora has had interactions with the broader Costa Rican scientific community (81%). In some cases, they were in permanent communication with former mentors or colleagues from their universities back home, underscoring an interest in staying current with the developments of these groups. In other instances, a closer relationship was established, including regular visits to Costa Rica to participate in seminars or workshops and active teaching in graduate programs in national universities. A few interviewees who did their Ph.D. studies abroad informed that a part of their research was carried out in their home country.

Some interviewees have promoted the development of internship programs for Costa Rican students in the universities where they study or work, and others have promoted the development of cooperation agreements and memorandums of understanding (MOUs) between foreign universities and academic institutions in the home country. This is the case of a scientist based at the Institut Pasteur in France, who has actively promoted cooperation and exchanges with the research community in the field of Microbiology, including a cooperation agreement between the UCR and this French institution.

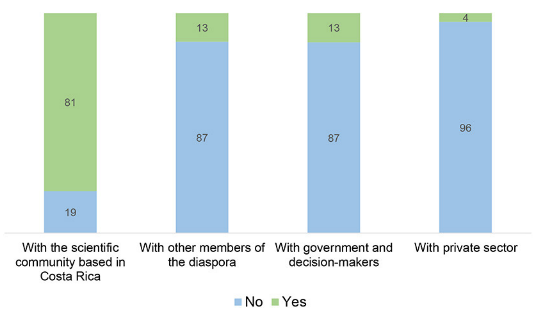

FIGURE 4
Percentage of members of the Costa Rican scientific diaspora who indicated collaborating with key stakeholders in the home country, by sector ($N = 121$).

Figure 4 also shows that only 13% of interviewees have had some interaction with other members of the diaspora, for example, one professor served as "Chair" of the doctoral thesis defense committee of a Costa Rican student at Stanford University, another person led a research project in the United States and invited other Costa Ricans to participate, and a group of people mentioned speaking as panelists at events organized by the diaspora abroad.

On a similar vein, only 13% of interviewees indicated having had some type of collaboration with the government or with decision-makers. A notable case is a scientist based in Europe who provided expert advice to the Costa Rican diplomatic delegation at the United Nations Framework Convention on Climate Change (UNFCCC). This example highlights the potential role of diaspora members in supporting diplomatic efforts, an especially critical function, considering that most Costa Rican embassies do not have a designated science and technology counselor (EURAXESS, 2022).

Diplomatic corps from Latin America are engaging with their diasporas in thriving ecosystems, as in the case of Boston, where the Consulate General of Mexico recruited 25 experts from the Mexican diaspora to form an advisory group that updates diplomatic personnel on the latest developments in STI. Something similar is being done by the Consulate General of Brazil, with the aim of connecting with its diaspora to promote the internationalization of Brazilian startups and companies in the United States (Ittelson and Mauduit, 2019). This illustrates the link between science and diplomacy in response to global challenges and countries' specific needs (Gluckman et al., 2017).

Our study provides other examples of interactions with the government, establishing collaborations with the national health system (the Costa Rican Social Security Fund or "CCSS"), the Central Bank, the National Statistics and Census Institute, and the ministries of agriculture and science and technology, as well as individuals who have served as delegate members in national elections organized by embassies and consulates abroad. While our analysis suggests limited connections between the Costa Rican government and its diaspora, this is not generalizable to other countries in Latin America. Mexico, for example, created the Institute for Mexicans Abroad and established a Consultative Council where elected diaspora members can make recommendations to the government on a wide range of issues (International Organization for Migration and Migration Policy Institute, 2012).

Finally, the interaction of the interviewed diaspora with the private sector in Costa Rica has been especially low (4%) and no concrete examples of collaboration with companies in the country were identified within our sample.

Despite the limited interaction with the private sector and other STI stakeholders, a key finding of our analysis is that there is a significant number of members of the diaspora who expressed an interest in maintaining contact and contributing scientifically to Costa Rica. Previous studies have highlighted that research on the needs and perceptions of the diasporas has been lacking and might be key to determining future policies directed at engaging with them (Séguin et al., 2006; Gëdeshi and King, 2019). To contribute to this specific gap, we analyzed the responses to four questions seeking recommendations from the diaspora on initiatives to support talent abroad, as well as incentives to retain scientific talent in the country and resolve the development needs of specific scientific areas. Our analysis uncovered three main incentives: (1) expanding research networks, (2) strengthening infrastructure, and (3) broadening cultural perception around STI.

Most of the interviewees highlighted that expanding research networks (92%) is a key incentive, including funding and expanding training opportunities abroad, promoting collaborations among the Costa Rican scientific community, organizing events, and promoting international relations and collaborations with higher education institutions abroad. These ideas were persistently recurrent throughout the 10-year period of interviews.

Some examples of specific demands in this area are: (1) the strengthening of existing or the creation of new databases with information about scientific talent abroad that can facilitate contact with ministries, as well as with public or private institutions and research groups; (2) the organization of online courses targeted to specific populations such as high school students, and (3) the establishment of pathways for the diaspora to receive Costa Rican students for internships and training.

Building scientific networks involving Costa Rican research groups and members of the diaspora is a key task that should be fostered by multiple mechanisms. These networks should be fluid and versatile, away from bureaucratic formalisms, and based on the shared interests of members of the Costa Rican scientific community, the diaspora, and groups from other countries in complex networking dynamics, along the spirit of what has been called "the new invisible college" (Wagner, 2008). The strengthening of academic "critical masses" in diverse

STI fields constitutes an element of attraction to members of the diaspora, whether to return and work in the country or to establish novel cooperation bonds. Sustained efforts and policies should be promoted to consolidate such an international networking arena.

A significant number of interviewees mentioned incentives regarding the improvement and strengthening of infrastructure (86%). In particular, the majority of the diaspora demanded a higher budget allocation to STI, funded by both the government and the private sector. Strikingly, the budget-related demands remained constant regardless of the year in which the interview was conducted.[7] Interviewees envision an ecosystem where academia, industry, and other sectors are more dynamically linked to foster attraction and further development of companies that carry out research and development (R&D), ultimately opening a broader set of opportunities that can attract members of the diaspora back to the country.

Further infrastructure incentives stated by interviewees - especially in the early years from 2011 to 2016- are the creation of research centers with modern equipment and access to databases that can keep up with development in the discipline, as well as programs and pathways for those scientists who wish to start a small business. It is interesting to note that requests for new physical infrastructure diminished considerably in more recent interviews. This may imply that there is a perception among the diaspora that the country has invested in this area in recent years.

Finally, there were additional demands related to the perception of science in society, as well as more job opportunities for the STI community and the redesign of the academic pathway within the country. In particular, 77% of people stated the importance of maintaining an updated listing of job offers in STI in Costa Rica, that is accessible to the diaspora. This need appeared continuously throughout the 10-year period. Additionally, many interviewees mentioned that clearer performance criteria and a merit-based academic system should be created.

The diaspora also considered that reinsertion initiatives for professionals abroad should be managed in a structured manner and as part of a directive national plan with a long-term vision, facilitating certain processes such as creating salary ranks that are based on both experience and academic degrees. The variety of needs expressed by the interviewees can be viewed within a more general frame of cultural and institutional changes aimed at raising the status of STI in the imaginary of our society as a whole, well beyond the STI community. This is a long-term goal that should be based on concerted national policies at various levels and involving many stakeholders.

Overall, these pressing demands call for a stronger commitment of public and private stakeholders to build a sustainable landscape for STI development, that not only will attract members of the diaspora, but will also retain young scientific talent by creating conditions for an expanding ground of international cooperation.

Conclusions and policy recommendations

This study was developed with two key objectives. First, to understand the main features of the Costa Rican scientific diaspora using TicoTal's 121 interviews published over a 10-year period. The second goal was to extract policy lessons from the diaspora experiences abroad. We studied their perspectives, resulting in an analysis that can inform national policies and investment strategies in R&D infrastructure and resources. The following policy recommendations emerged from this analysis:

It is crucial to position scientific diasporas as key resources in the scientific and technological development of countries. They must be reflected as critical actors on a nation's short, medium, and long-term STI policies. Government institutions must perform a systematic and recurrent mapping of their diasporas and their capacities and, on that basis, promote active networking with the home community in STI.[8]

The latter has been China's strategy, i.e., positioning the diaspora as a national asset in its global policies. In the last 20 years, they increased opportunities for the diaspora by fostering collaboration, short stays, and joint appointments between Chinese scientists who work abroad and their local STI community. This agrees with the perspectives of the Costa Rican diaspora collected in these interviews. In fact, China's approach has been crucial to its global rise in multiple scientific fields (Vogel, 2011; Marginson, 2022). New technological advancements have further bolstered this process. Indeed, different studies have highlighted that China, India, Mexico, and South Korea benefited from using information and communication technologies with their US-based diaspora. This provided a considerable comparative advantage over nations that do not make use of these strategies (Patterson, 2005; Grossman, 2010).

In addition, as mentioned by interviewees, academia should foster knowledge circulation by developing a set of incentives to attract the diaspora back, either temporarily or permanently.

7 As stated in the methods sections, the data was collected over a ten-year period, which may mean significant changes between interviews conducted a decade ago compared to the most recent ones. For this reason, a comparison was made between the answers of the early and late interviews to understand whether some demands of the diaspora had evolved over time or whether they remained constant.

8 The European Union Global Diaspora Facility is an initiative that is currently mapping diasporas around the world, in order to assist countries and diaspora organizations to collaborate more effectively with each other on development issues (Diaspora for Development, 2021). It can be accessed *via* the following link: https://diasporafordevelopment.eu/.

For example, local universities could invite diaspora members to conduct workshops and short-term stays, as a way to build long-term relationships that can be converted into more permanent positions. Furthermore, as exhibited in the Results section, another challenge for local universities is to enroll diaspora members in graduate and postdoctoral programs offered within the country. Bolstering these programs could attract talent during the training process and be attractive to diaspora members, further strengthening brain circulation and mobility of ideas.

Expert literature has additionally emphasized the importance of hiring researchers from abroad as a key indicator for the internationalization of research institutions (European Science Foundation, 2012). On some fronts, Costa Rica may find it challenging to recruit researchers with no previous ties to the country, but these appointments would not necessarily have to be permanent; they could be transitory in order to promote an "open door model" that benefits circulation. In fact, a university in Brazil offers an institutional affiliation, through which a work contract is not generated but grants scientists institutional support (Bonilla, 2022).

Moreover, a set of elements should be taken into account when signing future international agreements between universities: First, incentivizing more co-sponsorships of graduate studies abroad between home and host universities as a way to strengthen scientific linkages between countries (Jonkers and Tijssen, 2008). Also, our study, as well as previous ones, have shown the importance of financing short-term research internships in key universities that could eventually be converted into additional funding or lower barriers to further graduate studies and research opportunities for scientists (Burns, 2013).

However, engagement with the diaspora should not be viewed as exclusive to academia. As highlighted by the interviews, there is a need to involve both public and private sectors which, in turn, will also benefit from the knowledge, networks, and national ecosystems where the diasporas are based. A report by International Organization for Migration and Migration Policy Institute (2012) underscored the importance of creating better bridges with the private sector, sharing resources, promoting increased R&D private investment, and engaging STI diasporas in international projects.

Public-private partnerships can be established to guide diaspora investments in their home country. Such is the case of the Philippines, where Business Advisory Circles have been founded comprised of industry, government, and non-government organizations. They advise Filipinos abroad on where and how to invest in their country of origin (International Organization for Migration and Migration Policy Institute, 2012). In a similar vein, public institutions related to STI should engage with the diaspora in order to strengthen their own research agenda and harness opportunities in the institutions where members of the diaspora study or work abroad.

This study has included several successful examples of diverse and innovative ways in which other countries have engaged with their scientific diasporas. Similar mechanisms to bolster the diaspora in Costa Rica could have the following results in the midterm: (1) Increased access to new technological developments and (2) Increased production and improved knowledge circulation across the local scientific community and industry in the country. In the long term, these strategies could result in the strengthening of the nation's bilateral and multilateral relations using science and technology as a vehicle, an objective at the very core of science diplomacy.

Our paper provides new evidence about scientific diasporas. The biggest contribution is that it fills a gap in the literature providing more research into the needs and unique perceptions of diasporas. Despite the limitations, this study provides valuable information in order to build a roadmap to engage with scientific diasporas and benefit from their training and talent. Future research is crucially needed to better grasp the current efforts deployed in both public and private sectors and assess their efficacy and impact. This represents many methodological challenges; however, efforts should be made to collect this information in order to expand on the evidence presented in this paper.

Data availability statement

The raw data supporting the conclusions of this article will be made available by the authors, without undue reservation.

Author contributions

MJ-S, MG, and EL-S designed the research and database. KC, MJ-S, and EL-S collected the data and prepared the database. MS made the figures. MS and JG drafted the first manuscript. MJ-S, JG, EL-S, MG, and DM contributed to the subsequent writing and editing of the manuscript. All authors contributed to the article and approved the submitted version.

Conflict of interest

EL-S was employed by the company BridgeBio Pharma and Cystic Fibrosis Foundation.

The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The reviewer AQ-R declared a shared affiliation with the authors MJ-S, KC, and JG to the handling editor at the time of review.

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