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OPINION

Flux Science Without Borders: Strengthening Ecosystem Flux Capacity in Latin America

Tonantzin Tarin[1,2] | M. Susana Alvarado-Barrientos[2,3] | Eugenia González del Castillo[2,4] | Mónica Cervantes-Jiménez[2,5] | Zulia Sánchez-Mejía[2,6] | Alejandro Cueva[2,7] | Alejandro Delgado-Guerrero[8] | Dulce Flores-Renteria[2,9] | Jaime Garatuza-Payan[2,6] | César Hinojo-Hinojo[2,10] | Karem Meza[11] | David J. P. Moore[12] | Elí R. Pérez-Ruiz[2,13] | Ana Maria Restrepo-Acevedo[14,15] | Natalia Restrepo-Coupe[16,17] | Jaime C. Revenga[18] | Natalia E. Tonti[19] | D. Tyler Roman[20] | Milena A. González[8] | Jorge M. Uuh-Sonda[2,21] | Rodrigo Vargas[22] | Martha L. Vargas-Terminel[2,6] | Erik Velasco[23] | Samuel Villarreal[2,24] | Sebastien C. Biraud[25] | Margaret S. Torn[25] | Enrico A. Yepez[2,6]

[1]Instituto de Ecología, Universidad Nacional Autónoma de Mexico, Mexico City, Mexico | [2]Laboratorio Nacional CONAHCyT MexFlux, Monitoreo de Gases de Efecto Invernadero en Ecosistemas (LNC-MexFlux), Veracruz, México | [3]Red de Ecología Funcional, Instituto de Ecología A.C, Xalapa, Mexico | [4]Instituto de Ciencias de la Atmósfera y Cambio Climático, Universidad Nacional Autónoma de México, Mexico City, Mexico | [5]Laboratorio de Ecología Vegetal, Facultad de Ciencias Naturales, Universidad Autónoma de Querétaro, Queretaro, Mexico | [6]Departamento de Ciencias del Agua y Medio Ambiente, Instituto Tecnológico de Sonora, Ciudad Obregón, Sonora, México | [7]Departamento de Ciencias de la Sustentabilidad, El Colegio de la Frontera Sur, Unidad Villahermosa, Villahermosa, Tabasco, México | [8]Laboratorio de Ecosistemas y Cambio climático, Facultad de Estudios Ambientales y Rurales, Pontificia Universidad Javeriana, Bogotá, Colombia | [9]Group of Sustainability of Natural Resources and Energy, Saltillo Unit, SECIHTI-Center for Research and Advanced Studies of the IPN, Ramos Arizpe, México | [10]Departamento de Investigaciones Científicas y Tecnológicas (DICTUS), Universidad de Sonora, Hermosillo, Sonora, Mexico | [11]Department of Viticulture and Enology, University of California, Davis, California, USA | [12]School of Natural Resources and Environment, University of Arizona, Tucson, Arizona, USA | [13]Departamento de Ingeniería Civil y Ambiental, Universidad Autónoma de Ciudad Juárez, Ciudad Juárez, México | [14]Department of Biology, West Virginia University, Morgantown, West Virginia, USA | [15]O'neill School of Public & Environmental Affairs, Indiana University Bloomington, Bloomington, Indiana, USA | [16]Department of Ecology and Evolutionary Biology, University of Arizona, Tucson, Arizona, USA | [17]Cupoazu LLC, Etobicoke, Ontario, Canada | [18]Department of Mathematical Sciences, Section of Statistics and Probability Theory, University of Copenhagen, Copenhagen, Denmark | [19]Departamento de Ciencias de la Atmósfera y los Océanos, Facultad de Ciencias Exactas y Naturales, Universidad de Buenos Aires, Buenos Aires, Argentina | [20]EnviRoman Consulting LLC, Indianapolis, Indiana, USA | [21]Escuela Nacional de Ciencias de la Tierra, Universidad Nacional Autónoma de México, Mexico City, Mexico | [22]School of Life Sciences, Arizona State University, Tempe, Arizona, USA | [23]Molina Center for Energy and the Environment, Mexico City, Mexico | [24]Departamento de Ingeniería Sustentable, Centro de Investigación y Materiales Avanzados, Durango, Mexico | [25]Integrated Ecosystem Science Department, Lawrence Berkeley National Laboratory, Berkeley, California, USA

Correspondence: Tonantzin Tarin (ttarin@iecologia.unam.mx)

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ABSTRACT

The future of how we understand and manage ecosystems largely depends on direct and continuous observations that connect local territories to planetary processes. Latin America (LATAM: Mexico, Central and South America, and the Caribbean) hosts ecosystems critical for regulating global carbon, water, and energy cycles. However, persistent underinvestment in science and technology hampers the long-term monitoring capacity needed to advance regional priorities. Addressing the climate crisis requires investing in local researchers, technicians, and students, providing Earth System Science training that integrates biophysical and sociocultural knowledge. Although English is the *lingua franca* of science, training in native languages accelerates technical capacity, strengthens regional collaboration, and grounds solutions in local experience. Here, we present TAFE (*Taller de Aprendizaje de Flujos Ecosistémicos*) as an example of how regionally grounded, native-languages training can strengthen ecosystem flux science in LATAM and beyond. Such initiatives help decentralize knowledge, reduce the underrepresentation of Global South ecosystems in flux databases, and empower the next generation to lead research for both regional and global benefit.

1 | LATAM: Ecosystems, Biodiversity, Resources, and Global Pressures

Human activities have triggered an environmental crisis transcending political borders, where regions like LATAM offer critical perspectives. Home to 663 million people (8.1% of the global population; ECLAC 2024), LATAM includes six of the world's 17 megadiverse countries: Brazil, Colombia, Mexico, Peru, Venezuela, and Ecuador. The region contains ~60% of terrestrial biodiversity (UNEP-WCMC 2016), spanning all International Geosphere–Biosphere Programme land-cover classes. Consequently, LATAM encompasses diverse ecosystems—from tropical forests and savannas to high-altitude grasslands—within complex socio-ecological systems. Long-standing human-environment relationships, rooted in colonial legacies, have shaped land use and cultural practices that influence ecosystem resilience and define pathways toward restoration and climate adaptation.

LATAM is deeply embedded in the global economy. The region supplies minerals critical to the energy transition, producing roughly 35% and 40% of the world's lithium and copper, respectively (IEA 2023). It also plays a central role in global food systems, contributing around 14% of global agricultural and fisheries production and nearly half of net international agrifood trade (FAO 2021). Export-driven expansion of avocado, coffee, and livestock production has accelerated deforestation, biodiversity loss, soil degradation, and water scarcity (Gómez-Tagle et al. 2022). Although agroforestry and traditional milpa agriculture show that food systems can support more sustainable livelihoods, prevailing economic pressures continue to intensify habitat loss and socio-environmental conflicts.

2 | Scientific Capacity of LATAM Under Persistent Inequality

Although LATAM supplies critical natural resources and ecosystem services to the global economy, its scientific and educational capacity remains limited, uneven, and underfunded. Despite representing nearly a tenth of the global population, the region produces only 5% of global scientific output, reflecting persistent gaps in research investment and institutional support (Marzabal and Merino 2024). Although collaborative initiatives within the Earth System Science community have begun to address training disparities, access to advanced ecosystem research infrastructure remains limited. The region's capacity for raw material exports is not matched by investment in scientific and technological development, constraining its ability to generate the knowledge needed to understand and sustainably manage its ecosystems.

Structural barriers (limited budgets, unstable funding, and reliance on imported equipment) constrain LATAM research viability. Language barriers, paywalls, and restricted mobility (e.g., visa constraints) further hinder international collaboration, marginalizing underrepresented yet highly relevant research (Amano et al. 2023; Dáttilo et al. 2026). However, the climate crisis demands the context-driven science that LATAM researchers are uniquely positioned to provide. Global efforts to monitor carbon, water, and energy cycles—essential for improving climate models and meeting decarbonization targets—rely on sustained regional observations and expertise. Therefore, strengthening scientific capacity in LATAM is critical for climate governance from regional to global scales.

3 | Ecosystem Flux Science in LATAM

Ecosystem fluxes include the exchanges of matter and energy that connect local ecosystem processes to global climate dynamics, yet long-term observations remain unevenly distributed across the globe. LATAM hosts dozens of eddy covariance sites (56 currently registered in AmeriFlux) and an active research community with over three decades of experience in land–atmosphere science, supported by country-level initiatives such as ChileFlux (https://www.chileflux.cl/), BrasFlux and MexFlux (https://mexflux.gitlab.io/). However, large parts of the region remain underrepresented in global networks such as FLUXNET. Some LATAM flux sites are not led by locally based principal investigators, many depend on North American or European initiatives, and persistent constraints in funding, infrastructure, and data integration continue to limit regional capacity.

Recent analyzes show that only a fraction of LATAM's carbon uptake and evapotranspiration (ET) is represented in global datasets. Major gaps persist in tropical forests, peatlands, mangroves, drylands, and urban systems—ecosystems that disproportionately influence global cycles and remain primary sources of uncertainty in CO_2 exchange estimates (Villarreal and Vargas 2021). Managed croplands are also underrepresented, comprising only ~5% of LATAM sites in AmeriFlux, most of which are inactive. Given that agriculture accounts for ~70% of global freshwater withdrawals, expanding cropland flux observations is critical for improving ET estimates and water management (Melo et al. 2021; Salazar-Martínez et al. 2022). Strengthening LATAM's observational capacity is thus essential for both regional sustainability and global Earth System Science.

4 | Capacity Building for Flux Science: A Regional Training Model

Training remains a major structural constraint on the advancement of flux science across LATAM. Participation in workshops such as AmeriFlux's Fluxcourse (http://www.fluxcourse.org/) is often limited by cost, language, and mobility barriers. In this context, TAFE emerged from collaboration among MexFlux, AmeriFlux partners, and the FLUXNET Education Committee to strengthen continental collaboration and advance flux science in LATAM. Although core scientific and technical skills are shared, existing training models could not be directly transferred to the region; differences in scientific applications, social realities, infrastructure, and funding required a curriculum tailored to regional conditions. A dedicated curriculum development process ensured that the program was grounded in regional need from the outset (Testani et al. 2025).

When implemented, the TAFE initiative revealed demand from the LATAM scientific community far exceeding available capacity (a pattern consistent with documented barriers to training access across the Global South). Applicants represented diverse institutions and countries across the region, reflecting both broad geographic interest and the scarcity of locally accessible, language-appropriate training pathways. Selection criteria emphasized geographic diversity, equity, and representation from institutions with historically limited access to advanced flux training. Hybrid and recorded formats were incorporated to extend reach beyond on-site participants.

Delivered entirely in Spanish, TAFE aligned technical training with the region's linguistic, cultural, and ecological realities. Instruction by regionally based Spanish-speaking researchers drew on regional case studies and datasets to facilitate understanding of complex methodologies and their application to participants' home ecosystems.

Importantly, TAFE catalyzed a regional network for collaboration and data sharing (Figure 1). The initiative identified flux sites operating outside organized networks and created pathways for coordinated integration. Rather than a one-time event, TAFE fostered relationships that will strengthen collective capacity to monitor ecosystem change. In this respect, it is comparable to other international training initiatives that extend beyond local and regional boundaries. TAFE should be viewed as a regionally led, language-accessible, and scientifically rigorous training model whose significance lies in demonstrating that high-level Earth System Science training can be decentralized without compromising excellence.

5 | Urgent Investment in Flux Science Capacity

Strengthening LATAM ecosystem flux science via initiatives like TAFE is a strategic investment in global change resilience. These efforts build expertise, expand networks, and increase training access in underrepresented regions vital to Earth System Science. However, high demand for TAFE underscores both regional interest and fragile support structures; despite its success, lack of sustained funding persists as training needs outpace available resources.

Sustained investment in such initiatives is a global scientific imperative. They accelerate regional data sharing, improve understanding of carbon and water dynamics, and integrate missing observations into global syntheses—capacities critical for Earth observation, forecasting, and carbon accounting systems that rely on robust ecosystem data.

Expanding capacity requires partnerships rather than replicating models developed elsewhere. Hybrid approaches—combining in-person workshops, open-access Spanish materials, shared datasets, and remote collaboration—offer an efficient path to scale expertise. Partnerships with manufacturers, academic institutions, and international networks can reduce logistical barriers while fostering technical autonomy. Ultimately, the goal is to build capacity to operate, interpret, and innovate under local constraints.

The global environmental and climate crisis imposes a limited margin for action, thus investing in regional training initiatives such as TAFE is a strategic investment that ultimately

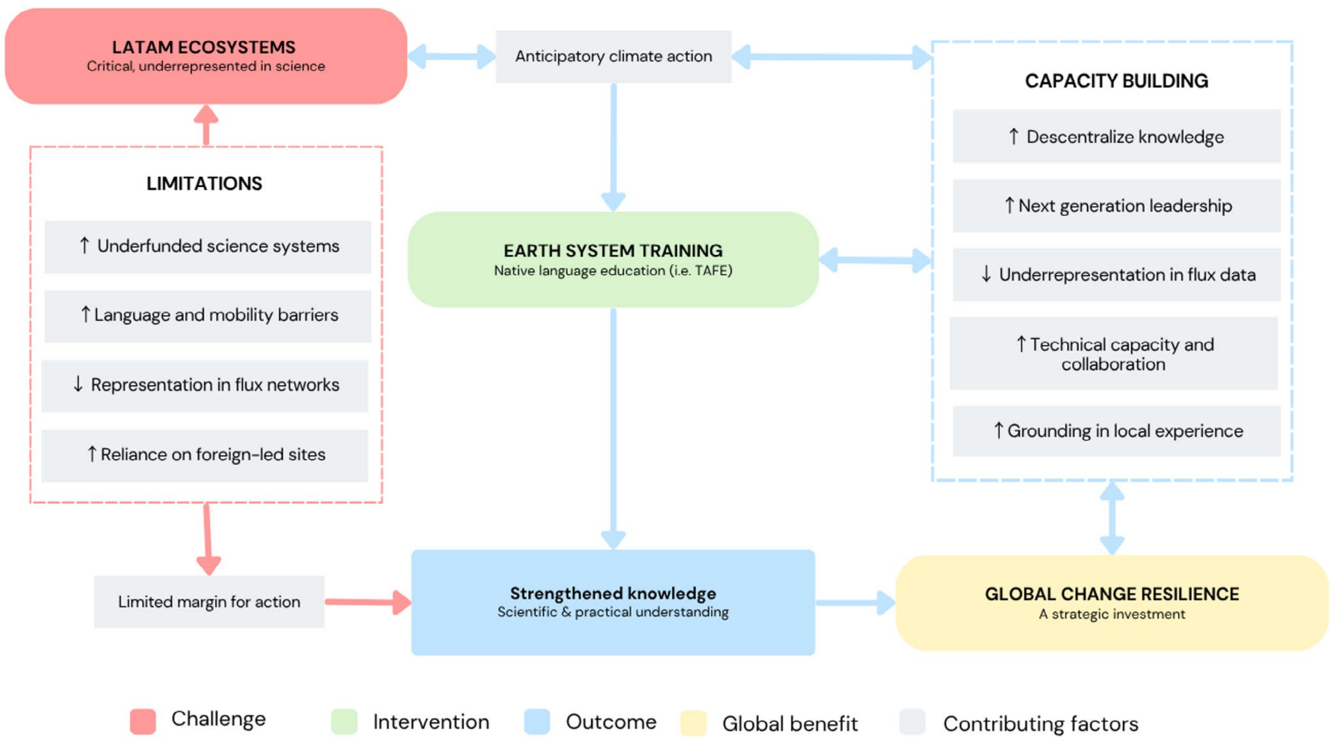

FIGURE 1 | From regional challenge to global resilience. Linking capacity building in LATAM ecosystem flux science from regional to global scale. Structural limitations, such as underfunded science systems and language and mobility barriers, constrain ecosystem flux research across Latin America, while regionally grounded, native-language training builds collaborative networks and next-generation leadership. Together, these efforts strengthen the scientific and practical knowledge needed to advance global change resilience.

strengthens the capabilities of the Earth System's scientific community. The question is not whether the world can afford to support LATAM's scientific capacity, but whether it can afford not to.

Author Contributions

Eugenia González del Castillo: conceptualization, writing – review and editing. **Karem Meza:** writing – review and editing. **Tonantzin Tarin:** conceptualization, writing – original draft. **Mónica Cervantes-Jiménez:** writing – review and editing. **Dulce Flores-Renteria:** writing – review and editing. **M. Susana Alvarado-Barrientos:** writing – review and editing, conceptualization. **David J. P. Moore:** writing – review and editing. **Alejandro Delgado-Guerrero:** writing – review and editing. **Zulia Sánchez-Mejía:** writing – review and editing. **Natalia E. Tonti:** writing – review and editing. **Milena A. González:** writing – review and editing. **César Hinojo-Hinojo:** writing – review and editing. **Ana Maria Restrepo-Acevedo:** writing – review and editing. **Rodrigo Vargas:** writing – review and editing. **Elí R. Pérez-Ruiz:** writing – review and editing. **Alejandro Cueva:** writing – review and editing. **Jaime C. Revenga:** writing – review and editing. **D. Tyler Roman:** writing – review and editing. **Samuel Villarreal:** writing – review and editing. **Natalia Restrepo-Coupe:** writing – review and editing. **Erik Velasco:** writing – review and editing. **Jaime Garatuza-Payan:** writing – review and editing. **Enrico A. Yepez:** writing – review and editing. **Jorge M. Uuh-Sonda:** writing – review and editing. **Margaret S. Torn:** writing – review and editing. **Martha L. Vargas-Terminel:** writing – review and editing. **Sebastien C. Biraud:** writing – review and editing.

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Conflicts of Interest

The authors declare no conflicts of interest.

Data Availability Statement

Data sharing not applicable to this article as no datasets were generated or analysed during the current study.

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