Eos
SCIENCE NEWS BY AGU

AGU
ADVANCING EARTH AND SPACE SCIENCES

COP28
SPECIAL EDITION

Beyond the Business Case for Diversity

Layers of Climate Change

Rethinking Urban Green Space

Taking Stock of Climate Action at COP28

This November in Dubai, scientists, government representatives, and climate advocates will gather for the United Nations Climate Change Conference, otherwise known as COP28. The focus will be on progress that signatories of the 2016 Paris Agreement have made toward their climate goals.

At *Eos*, we're doing some reflecting of our own—on the state of global climate action. In this special COP28 issue, we bring you stories that illustrate the challenge of meeting big climate goals while ensuring that the benefits of climate action are shared ethically and equitably with regions bearing the most significant impacts of climate change.

In "Layers of Climate Change," we see the wide-ranging ways Earth's interconnected systems are affected by human activity. The beautiful poster also shines a light on some of the creative adaptations scientists are pursuing to mitigate the effects of climate change, from developing carbon capture technologies to ensuring that smallholder farmers have access to data.

As cities become more populated, urban green space—and equitable access to it—is becoming a larger part of the climate discourse. In "Weighing the Benefits of Urban Greening" and "Growing Equity in City Green Space," we learn that one neighborhood's version of greening may not translate to another. When designing parks, gardens, and other green spaces, planners must consider local needs and use patterns, as well as the space's history, geology, and climate. Community engagement and ownership are key, researchers say.

Discovery, progress, and innovation are crucial to climate action and global in scope. In "Raising the Visibility of Latin American Science," we report on the ways the Global North's definition of success has steered international science. To gain visibility and advance their work, scientists from the Global South have traditionally been forced to align their research goals with those of the English-speaking Global North. A growing movement led by Latin American researchers and journals, however, is charting a new course in how science is evaluated and published.

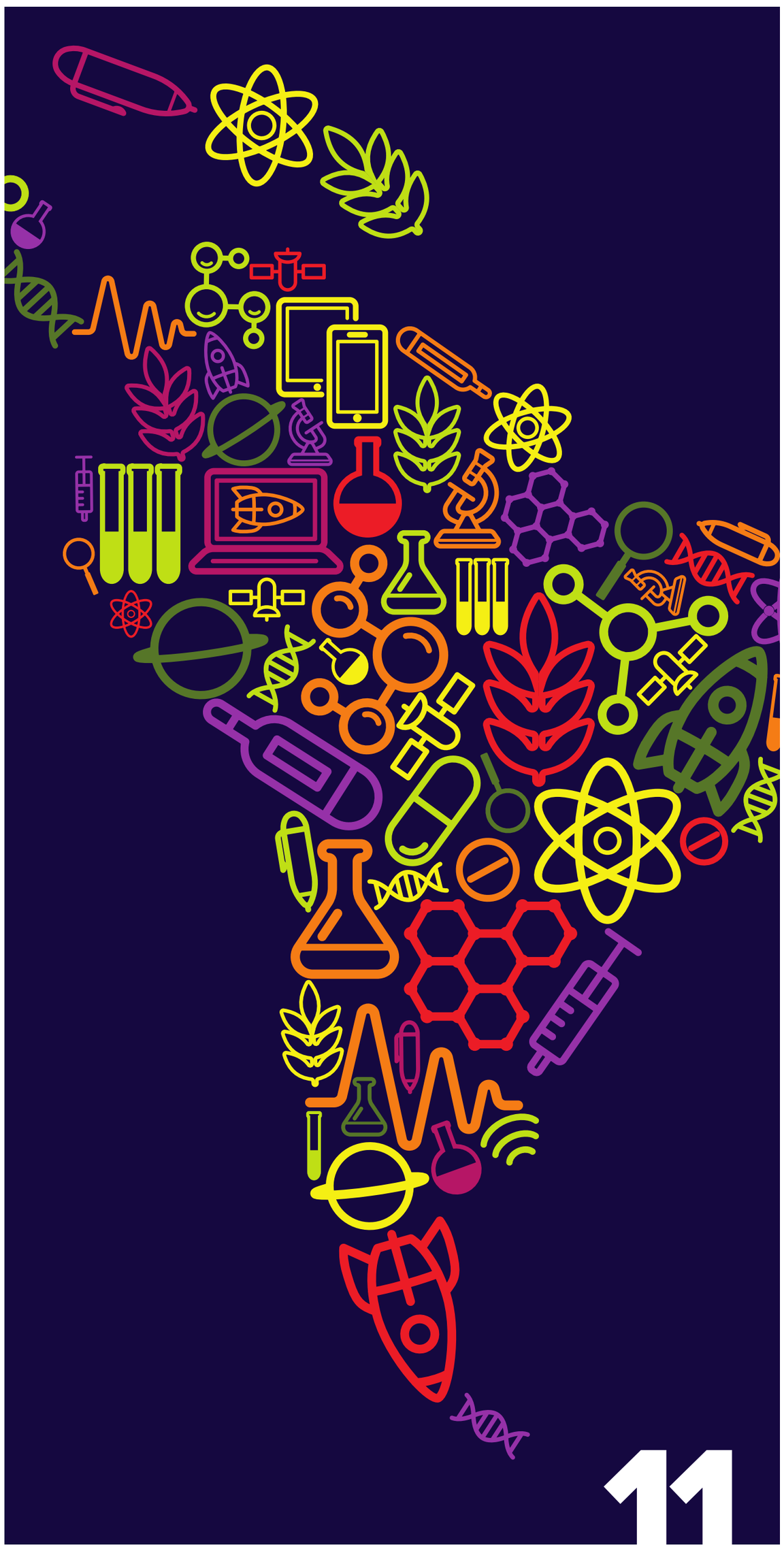
Ensuring diversity when addressing climate action as well as other scientific pursuits is a moral obligation, scientists say, not only a professional or financial opportunity. In the opinion "Moving Beyond the Business Case for Diversity," some scientists suggest that institutions take a hard look at the motivations and practices surrounding their efforts regarding diversity, equity, inclusion, and justice and create an environment in which "all members are heard, seen, and valued without having to provide justification for their inclusion."

COP28 attendees will grapple with complex scientific, ethical, and political hurdles. The world is facing a crisis, but the solutions are out there.

Jennifer Schmidt, Managing Editor

Growing Equity in City Green Space

By Kimberly M. S. Cartier



Raising the Visibility of Latin American Science

By Humberto Basilio

From the Editor 1

Illustration: Layers of Climate Change 3

News 4

AGU Research 7

Opinion 9

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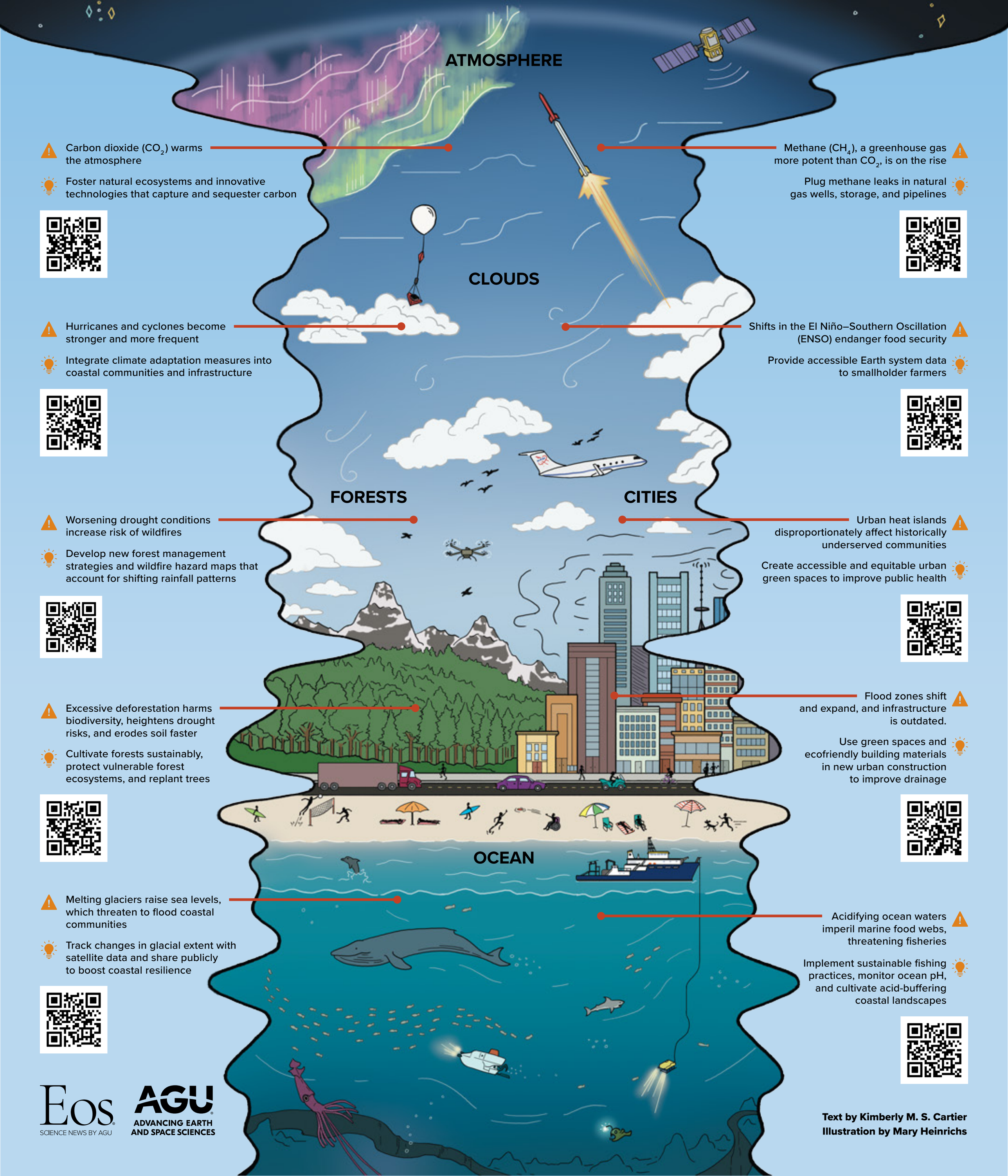
Layers of Climate Change

Issues and Solutions from Sky to Sea

Earth is an interconnected system—changes in one part ripple throughout the world. Anthropogenic climate change throws that system out of balance and endangers biomes, livelihoods, and lives. As countries around the world work to lower carbon emissions and switch to renewable energy sources, scientists also are developing innovative ways to mitigate climate impacts. Read below to learn about some of the ⚠ pressing problems the world faces and 💡 solutions in the works to help communities adapt. Scan the QR codes to learn more.



ATMOSPHERE

⚠ Carbon dioxide (CO_2) warms the atmosphere

💡 Foster natural ecosystems and innovative technologies that capture and sequester carbon

⚠ Methane (CH_4), a greenhouse gas more potent than CO_2, is on the rise

💡 Plug methane leaks in natural gas wells, storage, and pipelines

CLOUDS

⚠ Hurricanes and cyclones become stronger and more frequent

💡 Integrate climate adaptation measures into coastal communities and infrastructure

⚠ Shifts in the El Niño–Southern Oscillation (ENSO) endanger food security

💡 Provide accessible Earth system data to smallholder farmers

FORESTS

⚠ Worsening drought conditions increase risk of wildfires

💡 Develop new forest management strategies and wildfire hazard maps that account for shifting rainfall patterns

⚠ Excessive deforestation harms biodiversity, heightens drought risks, and erodes soil faster

💡 Cultivate forests sustainably, protect vulnerable forest ecosystems, and replant trees

CITIES

⚠ Urban heat islands disproportionately affect historically underserved communities

💡 Create accessible and equitable urban green spaces to improve public health

⚠ Flood zones shift and expand, and infrastructure is outdated.

💡 Use green spaces and ecofriendly building materials in new urban construction to improve drainage

OCEAN

⚠ Melting glaciers raise sea levels, which threaten to flood coastal communities

💡 Track changes in glacial extent with satellite data and share publicly to boost coastal resilience

⚠ Acidifying ocean waters imperil marine food webs, threatening fisheries

💡 Implement sustainable fishing practices, monitor ocean pH, and cultivate acid-buffering coastal landscapes

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AGU ADVANCING EARTH AND SPACE SCIENCES

Text by Kimberly M. S. Cartier
Illustration by Mary Heinrichs

Women take part in a discussion during Africa Human Rights Day in Abu Shouk, a camp for internally displaced persons in North Darfur, Sudan. Credit: UNAMID, CC BY-NC-ND 2.0 (bit.ly/ecbyncnd2-0)

10 Science Insights from COP27

A report aimed to add further scientific backing to the vast academic literature supporting policy discussion at 2022's Conference of the Parties of the United Nations Framework Convention on Climate Change (COP27). The report, "10 New Insights in Climate Science," was released by Future Earth, The Earth League, and the World Climate Research Programme (bit.ly/climate-science-insights). It complements the scientific reports issued by the Intergovernmental Panel on Climate Change (IPCC), according to Mercedes Bustamante, an editorial board member of the report.

This story is also available in Spanish

"Unlike the IPCC reports, which are not policy prescriptive, the Insights report is openly aimed at policymakers—not just in national governments but also in the local and regional spheres, as well as to those in the private and financial sectors," said Bustamante, an IPCC coauthor and systems ecology researcher at the University of Brasilia in Brazil.

"The report is based on new knowledge that emerged in the [preceding] 12 months... We start after the COP each year, and the process goes up to the following COP," explained Wendy Broadgate, a global hub director at Future Earth and a member of the report's editorial board.

"As global temperatures rise, adaptive responses become less effective."

The 2022 report included the expertise of more than 60 researchers from across the globe, as well as that of another 15 on the editorial board. "And we pay very close attention to the balances of expertise, gender, and geography among authors," added Broadgate.

From adaptation to finance, here are takeaways from the 2022 report:

1. The idea of "endless adaptation" is a myth. In many parts of the world, societies and ecosystems are already facing limits to climate change adaptation. "As global temperatures rise, adaptive responses become less effective," the authors write, and even effective adaptation measures will not be able to stave off all loss and damage. According to the authors, mitigation efforts are "critical to avoid widespread breaching of adaptation limits," and ambitious adaptation plans are urgent.

2. Vulnerability hot spots abound in regions at risk. Countries most vulnerable to the impacts of climate change have a climate-driven hazard mortality rate 15 times higher than the least vulnerable countries, the authors note. Today about 1.6 billion people live in highly vulnerable areas across Africa, Asia, Central America, and the Middle East—and the number is expected to double by 2050. "These regions are subject to multiple sources of stress and have less capacity of response as environmental frailty merges with social vulnerability," Bustamante said. Prioritizing international agreements that protect carbon sinks and biodiversity hot spots is one way to deal with the problem, the authors write.

3. The climate-health nexus will face new threats. Climate change is already affecting human, animal, and environmental health across the globe and is responsible for almost 40% of the world's heat-related deaths. It will continue to drive an increase in wildfires and outbreaks of waterborne and vector-borne diseases. Countries should consider the cost of inaction and readjust their budgets to make sure they can tackle climate-health vulnerabilities and invest in adequate prevention, the authors suggest.

4. Climate-induced migration will increase. Extreme weather events are already forcing vulnerable groups to move across the globe. Migration will likely increase as communities become unable to adapt. The authors suggest that policymakers shift from a reactive response (dealing with emergencies once they have taken place) to an anticipatory approach, which involves long-term planning and management.

The authors suggest that policymakers shift from a reactive response to an anticipatory approach.

5. Human security requires climate security. Climate change can trigger violence by deepening already existing conflicts and vulnerabilities. The Russian invasion of Ukraine, the authors write, revealed food and energy vulnerabilities associated with a dependency on fossil fuels. The authors suggest that scaled responses to conflict, involving regional, national, and international institutions, are required.

6. Sustainable land use is essential to meeting climate targets. Deforestation associated with agriculture is a major contributor to climate change. At the same time, the effects of a changing climate are putting agricultural activity at risk. Effective national policies supporting the transition to more sustainable and resilient land management practices are among the key actions to smarter and better land use, the report suggests.

7. Financial institutions are falling short of sustainability goals. Most of today's sustainable finance practices, the authors point out, are all too familiar: Capital is used within existing business models instead of being used in new and effective ways to tackle climate change. The financial sector is simply not moving at the speed the world needs to have real action on climate change. One way decisionmakers can address the issue, the report suggests, is by developing strong policies and regulations that demand "high levels of transparency and accuracy in the reporting of the emissions associated with investments, savings and economic activity."

8. The world needs urgently to address loss and damage. As infrastructure is threatened by extreme events and regions cede territory to rising sea levels, losses and damages associated with climate change are already a reality in many parts of the world. Some losses, the authors point out, can be calculated in monetary terms, but "there are also non-economic losses and damages that need to be better understood and accounted for." The report suggests that the world develop a coordinated global policy response to the challenge.

9. Inclusive decisionmaking is key for climate-resilient development. As climate change will affect all individuals one way or another, everyone should have a say in the choices that will affect their future. Inclusive decision-making, the authors write, "has been shown to lead to better and more just climate outcomes." Policies supporting the development, assessment, and expansion of community-led initiatives are effective ways to address climate justice.

10. The world can break down structural barriers. The gap between national pledges and emissions reductions required by the Paris Agreement is widening, the report warns. The world is stuck on social norms that prioritize continuous consumption and on business models that privilege nonstop production. One of the ways to break away from these structural barriers, according to the report, is to create and implement legal instruments to address inequality and injustice.

By **Meghie Rodrigues** (@meghier), Science Writer

Citation: Rodrigues, M. (2022), 10 science insights for COP27, *Eos, 103*, https://doi.org/10.1029/2022EO220531.

One study found inequity in access to urban parks in Hyderabad, India. Credit: iMahesh/Wikimedia Commons, CC BY-SA 4.0 (bit.ly/ccbysa4-0)

Weighing the Benefits of Urban Greening

Cities suffer from the urban heat island effect and localized flooding. Urban planners often suggest adding parks and embracing construction practices like indoor and outdoor living walls and green roofs, practices that can have cooling effects and can lead to the absorption of stormwater runoff.

But new research finds that urban greening practices have different effects in different environments (bit.ly/urban-greening-tradeoffs). Communities will be better served by identifying their greatest need and considering which greening practice will best address it.

This story is also available in Spanish and Hindi

Urban greening has a lot of potential benefits, but there is also "a temptation to assume the benefits in one context can translate to another," said Mark Cuthbert, lead author and a principal research fellow at the School of Earth and Environmental Sciences at Cardiff University in Wales. Cuthbert and his coauthors undertook the research to understand the effects of urban greening practices on different ecosystems.

One major finding is that in arid climates, urban greening works best when focused on reducing surface water runoff, whereas in more humid climates, cooling is more likely to be a stronger benefit. Because of this relationship, "common urban greening strategies cannot yield high performance simultaneously for addressing both urban heat island and urban flooding problems in most cities globally," Cuthbert explained.

In arid climates, urban greening works best when focused on reducing surface water runoff, whereas in more humid climates, cooling is more likely to be a stronger benefit.

Other factors, such as substrate thickness, may determine how beneficial urban greening is. In general, thicker soils like those in urban parks have greater moisture storage capabilities and thus can provide some measure of both cooling and water retention benefits, in addition to being more robust in extreme weather events. Thinner substrates like green roofs provide only "reasonable performance," according to the study.

Harini Nagendra, who leads the Center for Climate Change and Sustainability at Azim Premji University in India, was not involved in the new study but highlighted the need for further research on the topic. "Tropical cities will need to follow different strategies from temperate ones. But most of these models and field studies have been done in temperate cities, so we don't really know enough to devise best strategies for tropical cities," she said.

The Need for Local Planning and Community Engagement

Although an urban planner may want to install a park on the basis of its localized climate benefits, factoring in what community residents actually want in their neighborhoods "adds several layers of complexity" to urban greening policies and projects, Nagendra said.

She is the coauthor of a January 2021 paper in *Urban Forestry and Urban Greening* that found inequities related to gender and income in accessing urban parks in Hyderabad, a city of more than 6 million in central India (bit.ly/urban-parks-Hyderabad).

The study focused on four parks in the city and found that low-income groups were marginalized. For example, the parks all had entry fees, as well as regulations that prohibited flower harvesting. In addition, women residents raised safety concerns. Urban parks like those in Hyderabad must be "reimagined as commons, with access to all," the paper concludes.

Creating green spaces can also contribute to social inequities through the process of gentrification, experts have said. Isabelle Anguelovski, director of the Barcelona Laboratory for Urban Environmental Justice and Sustainability, said that green infrastructure can contribute to "higher land and home prices and therefore displacement of the most socially fragile residents due to processes of green gentrification."

Cities should be both green and just, Anguelovski added, and a narrow perspective of greening that focuses on only the ecological benefits could risk the creation of social inequalities if it is not accompanied or even preceded by strong affordable housing and inclusive greening policies.

A narrow perspective of greening that focuses on only the ecological benefits could risk the creation of social inequalities.

Earlier reports have highlighted how the involvement of local communities could help create environmentally just green spaces. Cuthbert added that implementation strategies need to "take account of a much wider set of social, cultural, and economic factors."

"Is it an area where children are deprived of play spaces and there is high obesity? Do [residents] want safe open spaces for children to play?" Nagendra asked. "Or is it a food desert, where it is more important for them to have community gardening areas where people can grow their own food?"

Such greening projects "can't be set in stone," Nagendra said. The creation of green spaces "will set into motion social-ecological transformations in the landscape and in the community, all of which may not be anticipated in advance."

For example, in tropical areas, greening measures that inadvertently increase water absorption could lead to waterlogged areas where mosquitoes thrive. The diseases they carry could then call for draining interventions, underscoring the importance of adaptation and constant reevaluation in greening practices.

Ultimately, the creation of green spaces requires "codesign between scientists, experts, and local residents, and that is an interactive process where there are no easy shortcuts," Nagendra said.

By **Rishika Pardikar** (@rishpardikar), Science Writer

Citation: Pardikar, R. (2022), Weighing the benefits of urban greening, *Eos, 103*, https://doi.org/10.1029/2022EO220115.

Leila Mafra Conceição, one of the women involved in the agroecological log project in the rural area of Camiranga, Pará state, Brazil, fills in a log at a workshop that took place in May 2022. Credit: Suelany Sousa da Silva/FASE/Fundo DEMA, All rights reserved

How Climate Change Is Affecting Women in the Amazon

This story is also available in Portuguese

According to the United Nations, climate change and its effects are not gender neutral: Women and girls are hit the hardest, as the climate crisis deepens already existing gender inequalities.

This is true especially for the developing world. According to a 2022 UN report, women have lower survival rates when faced with environmental disasters. They are also highly vulnerable to gender-based violence in the aftermath of extreme events. Agriculture, a deeply weather-dependent activity, is still the largest employer of women in low- and lower-middle-income countries. Though they are almost half of the agricultural workforce globally, women own less than 13% of agricultural lands, according to the UN.

In the Amazon, changes in hydrological cycles pose a special threat to traditional groups. Women bear the brunt of the effects, according to Luisa Viegas, an ecology researcher at the Federal University of Bahia in Brazil. "The change in river levels affects riverine communities, and when extreme events happen, women are especially affected, as they are usually home and take up most of the domestic work," Viegas said.

Research has consistently pointed to increasing changes in rain cycles and drought in the Amazon. One study suggested that areas deforested for more than a decade receive less rainfall than others during the dry season. NASA released another study in which researchers concluded that the atmosphere over the rain forest has been increasingly dry as a result of deforestation and the burning of forests. A review found that changes in land use, especially in the southern Amazon, affect atmospheric circulation: The regimes of dryness and rainfall are quickly changing.

"When extreme events happen, women are especially affected, as they are usually home and take up most of the domestic work."

Traditional communities that work the land, especially women who care for small family farms, are feeling those changes already. A primary impact is on food security, observed Mônica Vasconcelos, a sociobiodiversity researcher at the State University of Amazonas. In the Negro River region close to Manaus, capital of Amazonas state, rising temperatures limit outdoor working hours. Nearer the Juruá River (in the west), flooding extremes mean reduced cassava production.

"The result of both flood and drought is increased food insecurity and less revenue for local communities. For women it is even worse, as they have a double work journey and do not receive twice the compensation," Vasconcelos said.

In Brazil, women are a powerful workforce behind family farming—according to Brazil's National Supply Company (CONAB), female participation was 80% higher than male participation in family farming in 2019. Family farms in the Amazon are particularly vulnerable to flooding and drought. "Soils in the Amazon are really acidic, so the overflow of rivers helps balance the soils' pH," said Marcela Vecchione, an Amazonian studies researcher at the Federal University of Pará.

"Women usually sow the floodplains after the rainy season, but the lack of [accurate precipitation forecasting] harms the management of small agricultural systems," she said.

Unpredictable conditions not only confound the agroecological calendar but also harm efforts to collect seeds for future production seasons, Vecchione said.

Finding Solutions

Challenged with the current scenario, women in the Amazon are working on solutions. One project addressing the issue is Amazonian Agroecological Logs (Cadernetas Agroecológicas na Amazônia), in which women keep track of the food they produce, consume, exchange, donate, and sell. Created in 2011 at the Center for Alternative Technologies of the Zona da Mata region in the eastern part of Brazil's Minas Gerais state, the log system is familiar to rural communities in Brazil.

Coerama (Kalanchoe brasiliensis), *kiss-me-quick* (Portulaca pilosa), *and wax mallow* (Malvaviscus arboreus) *are among the herbs most commonly cultivated on family farms in Brazil and were extensively used during the pandemic. This image was taken at a workshop in July 2022 in Jacarequara, Pará state. Credit: Suelany Sousa da Silva/FASE/Fundo DEMA, All rights reserved*

In 2022, the Federation of Organs for Social and Educational Assistance (FASE), a nongovernmental organization, together with the nonprofit Dema Fund, undertook the project in Pará state, in the Amazon region. According to Beatriz Luz, an educator at FASE and the Dema Fund, the organization followed about 90 women in Pará state.

"Every day, women write down all they do with their production and account for what they would pay or get, so they have an idea of their work's worth—something that has been historically made invisible," said Luz. In a previous round of the project, the logs revealed that women earned an average of 400–600 reals (US$80–$120) a month—about half of Brazil's current minimum wage. Even that value, according to Luz, is an underestimate, "as women do not always note the seeds they exchange, for example."

The project, which "sheds light on [what is] very often invisible work, fosters food security," and contributes to local biodiversity, Luz explained. (One log documented 246 species in a single backyard garden plot.) The logs have also cataloged rural work, allowing the women to apply for retirement benefits from the government. By keeping effective records, women farmers are able to scale their production—some family farms manage their crops in a way to sell to local schools or businesses, for instance, whereas others diversify to extend growing seasons or include animal husbandry.

In another project, this one close to the Negro River in São Gabriel da Cachoeira, Amazonas state, members of the Indigenous Women's Association of Alto Rio Negro are working to pass on and preserve their Traditional Knowledge of agricultural production. Older women lead workshops in which they teach younger generations to grow beans, cassava, and other crops. It has been a challenge to follow the tradition by the book as rainfall patterns have changed, said Elizângela Costa, a Baré Indigenous leader who directs the Women's Association.

"We're looking for new alternatives at the same time we want to protect our Traditional Knowledge and value our fellow women. It hasn't been easy, but it's important to care for our community, our territory, and our future generations," Costa said.

By **Meghie Rodrigues** (@meghier), Science Writer

Citation: Rodrigues, M. (2022), How climate change is affecting women in the Amazon, *Eos*, *103*, https://doi.org/10.1029/2022EO220527.

Reducing fossil fuel emissions from power plants would also mitigate the death toll from air pollutants like ozone. Credit: Oleg Savitsky/Wikimedia Commons, CC BY-SA 4.0 (bit.ly/sc2qsx4-0)

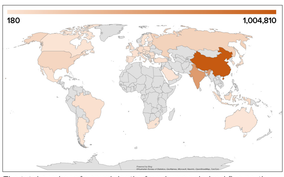
The Global Health Benefits of Going Net Zero

Fossil fuel combustion doesn't only produce greenhouse gases that heat the planet; it also emits air pollutants that harm human health. Fine particulate matter and ozone, for example, have been linked to fatal lung and heart issues. And a study published in *GeoHealth* adds to the growing body of research that shows that when countries reduce their greenhouse gas emissions, the associated improvements in air quality could save countless lives.

This story is also available in Arabic

The researchers used computer simulations to quantify the deaths associated with power plant emissions globally. Then they modeled how those numbers might change if G20 countries, which include the world's biggest economies, kept on pace to reach their net zero emissions goals.

The team concluded that particulate matter and ozone caused more than 2.2 million premature deaths each year in G20 countries. Reducing emissions in these countries from power plants alone could reduce that death toll by nearly 300,000 lives annually by 2040.



The total number of annual deaths from human-derived fine particulate matter and ozone pollution in G20 countries, where darker colors reflect a greater number of annual deaths. Credit: AGU

Air Pollution Across Borders

The G20 represents 19 of the world's most economically developed countries and the European Union. This collective accounts for more than 90% of the world's gross domestic product, more than 60% of the world's population, and 80% of greenhouse gas emissions.

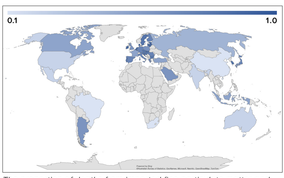
In an effort to fight climate change, many of these countries set goals to minimize their carbon footprint by reducing fossil fuel combustion. Because fossil fuel combustion produces pollutant emissions that increase concentrations of ozone and fine particulate matter, the clean energy transition could yield public health benefits, too.

Nations need to cooperate to realize these life-saving effects.

To quantify how air pollution from these countries affects public health, the researchers performed computer simulations using meteorological data from the NASA Global Modeling and Assimilation Office.

They found that China, India, and the United States, which have high emissions and large populations, experience the greatest number of air-quality-related deaths among G20 countries. Still, air pollution knows no national borders, and emissions from one nation affected nearby nations, too.

"People can be exposed to air pollution in countries where the pollution didn't originate due to their geographic location and the prevailing wind patterns," said Omar Nawaz, an air quality scientist at the University of Colorado Boulder and lead author of the study. "For example, we found that South Korea and Japan were more impacted by emissions from China than they were by domestic pollution sources."



The proportion of deaths from imported fine particulate matter and ozone pollution in G20 countries, where darker colors reflect a greater proportion of deaths. Credit: AGU

Reduce Emissions to Save Lives

The scientists then modeled how many lives could be saved if power plants in G20 countries, which are one of the largest emission sources for air pollution, achieved their net zero goal by their target dates. They found that by 2040, even before any of these nations reach their net zero goal, reducing emissions from power plants alone would save approximately 300,000 lives each year.

This estimate does not account for sources of emissions other than power plants, and according to the researchers, the health benefits would continue to grow if nations stayed on pace with their goals after 2040 (see Table 1).

Because air pollution crosses political borders, nations need to cooperate to realize these life-saving effects.

Table 1. Possible Avoided Deaths If G20 Countries Stay on Track with Their Climate Change Mitigation Plans

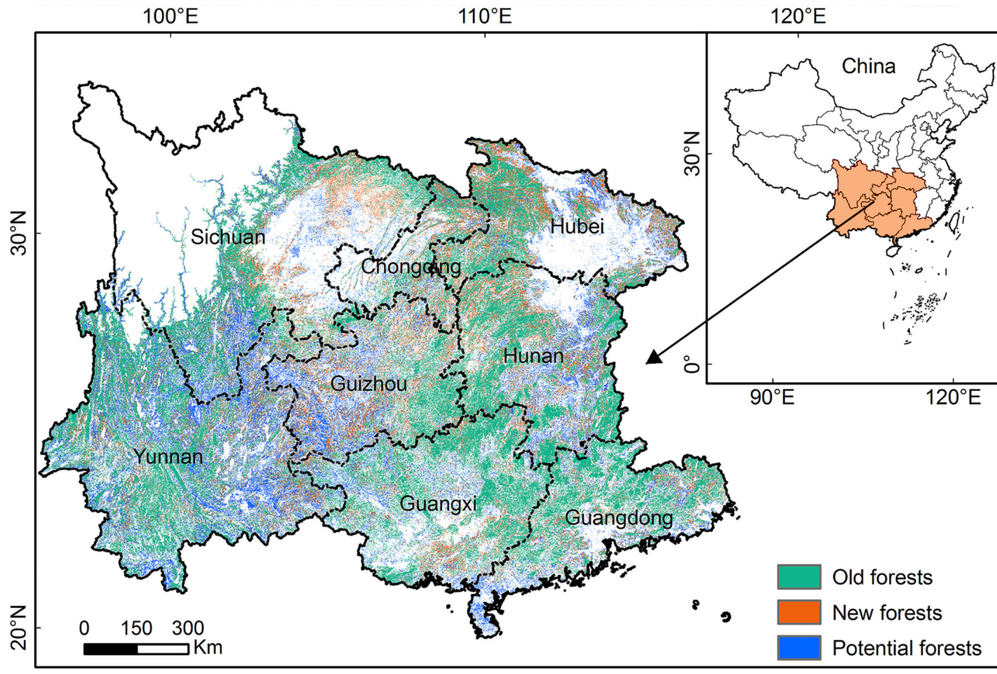
COUNTRY	DEATHS AVOIDED IN G20 COUNTRIES, 2040
NET ZERO TARGET: 2045	
Germany	2,900
NET ZERO TARGET: 2050	
Argentina	500
Australia	800
Brazil	8,500
Canada	1,300
European Union	8,900
Japan	3,500
South Africa	2,100
South Korea	2,700
United Kingdom	1,100
United States	16,700
NET ZERO TARGET: 2053	
Türkiye	2,800
NET ZERO TARGET: 2060	
China	70,500
Indonesia	13,800
Russia	14,600
Saudi Arabia	2,100
NET ZERO TARGET: 2070	
India	135,900

"For example, if Canada worked toward reaching its net zero emissions goal, the main country reaping those benefits would be the United States because of its proximity to Canada and larger population size," Nawaz said. Likewise, emissions reductions in the United States would yield public health benefits for Canada.

Nawaz said that scientists could use the approach outlined in this study to assess how reducing emissions in other sectors such as agriculture could also reduce pollution's death toll. Applying it broadly could reveal the full life-saving potential of climate change mitigation. (*GeoHealth*, https://doi.org/10.1029/2022GH000713, 2023)

By **Kirsten Steinke** (@Kirsten_Steinke), Science Writer

Citation: Steinke, K. (2023), The global health benefits of going net zero, *Eos, 104*, https://doi.org/10.1029/2023EO230046.



Current and potential forest areas in the study area of southern China. "New forests" were forested between 2002 and 2017, whereas "old forests" existed prior to 2002. "Potential forests" are not currently forested but were identified by the analysis as suitable for forest growth. Credit: Zhang et al.

Quantifying the Potential of Forestation for Carbon Storage

Large-scale forest planting projects have been proposed as a carbon sequestration strategy for mitigating anthropogenic climate change. In southern China, tree-planting initiatives over recent decades have significantly expanded forested areas and sequestered substantial amounts of carbon in tree biomass. Understanding both the historical carbon sequestration and the potential for future carbon storage through forestation is important for developing climate change mitigation strategies.

Zhang et al. use a combination of data synthesis, remote sensing, and machine learning approaches to estimate the historical trajectory and the potential carbon storage capacity of forests in southern China. They find that regional forest carbon storage has increased over the 15-year study period, signifying successful carbon sequestration, and they identify opportunities for further increasing carbon density in forestation projects. However, they also find that forests in the region have already achieved more than 73% of their carbon storage capacity, indicating that afforestation alone will ultimately face limits as a carbon sequestration strategy. (*Earth's Future,* https://doi.org/10.1029/2022EF002674, 2022)

This story is also available in Simplified Chinese

By **Benjamin Sulman,** Associate Editor, *Earth's Future*

15 LIFE ON LAND

The research reported here supports **Sustainable Development Goal 15**. AGU is committed to supporting the United Nations 2030 Agenda for Sustainable Development, which provides a shared blueprint for peace and prosperity for people and the planet, now and in the future.

Illustration/Adobe Stock

Moving Beyond the Business Case for Diversity

Over the past few years, efforts to elevate diversity, equity, inclusion, and justice (DEIJ) in the geosciences have thankfully gained momentum as these imperatives are more broadly discussed in academic and research circles, the private sector, and professional societies like AGU. In many cases, institutions have adopted initiatives and created programs focused on DEIJ that are guided by mission statements espousing commitments to do better. These statements, which distill institutions' motivations for pursuing DEIJ, vary in their phrasing but almost universally revolve around a similar theme.

Beginning in the 1960s, proponents of efforts to diversify and broaden participation in academia, government, and private industry mostly focused on complying with affirmative action measures. These measures were spelled out in President John F. Kennedy's Executive Order 10925 in 1961 and the Civil Rights Act of 1964, which looked to ensure that employers treated people "without regard to their race, creed, color, or national origin" and to ban employment discrimination based on those attributes.

Since those early days of affirmative action, the primary reasoning of companies and institutions of higher education or research has evolved into what is often referred to as the business case, or the instrumental rationale, for diversity (*Starck et al., 2021*). This rationale makes the argument, concretely, that a variety of perspectives and backgrounds improves the quality of research, contributes to solving big scientific challenges, helps institutions attract more students and scientists, and improves employee happiness, among other benefits. Such justifications have been necessary to convince institutional leaders to buy in to the idea of investing in and supporting measures related to broaden diversity and inclusion. And as the business case for diversity has gained popularity, we have seen references to it multiply, appearing in courtesy scholarly papers, on institutional websites, and in funding solicitations and subsequent grant proposals.

The business case for diversity may thus seem sound. But it is not enough and is potentially even harmful. Put another way, it is inappropriate as the driving motivation for DEIJ work because it fails to acknowledge the paramount moral rationales for this work; more important, it can create unintended negative impacts, particularly for students and scholars who identify as Black, Indigenous, and People of Color (BIPOC) and for other marginalized groups. We therefore argue that institutions should reframe their views of DEIJ and their approaches to diversify their institutions.

> "The business case for diversity may seem sound. But it is not enough and is potentially even harmful."

> This story is also available in Arabic

The Widespread Use of the Business Case

A study by *Starck et al.* [2021] examined both instrumental and moral rationales for diversity in U.S. universities and how different populations attached to the different arguments. The researchers found that the business case is the most commonly applied argument for diversity efforts in higher education. Further, they found that white students and their parents reacted positively to those arguments, whereas Black students and their parents preferred moral arguments for diversity.

The *Starck et al.* [2021] study inspired us to conduct an extensive review of diversity statements from all 42 Federally Funded Research and Development Centers in the United States. Like that study, our analysis showed the prevalence of the business case throughout this research community. In fact, we found that nearly all of the diversity statements issued by centers or their managing organizations focused solely or primarily on the contributions of diversity to productivity, creativity, and employee satisfaction—in other words, the business case.

For example, a statement by the National Renewable Energy Laboratory (NREL) reads, "At NREL, we believe that fostering an inclusive work environment maximizes the unique talents and innovative ideas of every employee. Our diverse backgrounds and expertise from across the globe enable the laboratory to create clean energy solutions built upon a wide range of experiences and viewpoints." Similarly, a statement by the Southwest Research Institute (SwRI), which manages the Center for Space Weather Regulatory Analyses, says, "Diversity and inclusion are key ingredients in the advancement of technology, and this is why SwRI aims to attract, develop and retain a highly diverse workforce at all levels." The managing organization of the National Center for Atmospheric Research, the University Corporation for Atmospheric Research, is one of only few examples we found whose diversity statements mentioned moral reasons, such as that it's "the right thing to do."

We don't dispute the validity of the business case; indeed, many studies have borne out its arguments. Diverse teams that bring a wider array of knowledge and experience to the table are more creative and bring fresh lens for research and scholarly excellence, producing ideas that are both more innovative and more feasible than those produced by homogeneous groups (*McLeod et al., 1996*). However, although the business case makes valid points, it is ethically flawed.

A Flawed Approach

The business case is problematic because it focuses on the needs and gaps of the institution rather than on addressing exclusion as a justice issue. It's a utilitarian approach, justifying the inclusion of BIPOC and other marginalized people by their transactional benefits to the majority instead of acknowledging the individual humanity of people. We see this focus in the private sector as well when companies try to reach new consumer populations. Thomas [2004] described how the chief executive officer of IBM saw the company's diversity efforts: "We made diversity a market-based issue.... It's about understanding our markets, which are diverse and multicultural." By deliberately seeking ways to more effectively reach a broader range of customers, IBM has seen significant bottom-line results.[1]

In addition to being ethically flawed, the business case relies heavily on making arguments for why an institution should invest in BIPOC and people from other marginalized backgrounds. This approach forces people from these groups into the position of having to explain why they should be seen, heard, and hired. Constantly having to justify one's value or worthiness as a result of systemic biases and racism can cause highly capable people to second-guess themselves (*Tulshyan and Burey*, 2021). BIPOC, for example, should not have to convince people to allow them into different spaces, whether in science, technology, engineering, and mathematics (STEM) or in other fields, and they should not have to constantly second-guess the reasons they are in these spaces.

> Emphasizing the business case can be unfair and even harmful for BIPOC and people from other marginalized groups, and it can unintentionally build unreasonable expectations for individuals.

Thus, emphasizing the business case can be unfair and even harmful for BIPOC and people from other marginalized groups, and just as affirmative action efforts often led to unjust assumptions that some people were hired on the basis of quotas, not qualifications, it can unintentionally build unreasonable expectations for individuals. Under the assumption that scientific output and innovation will improve with more diverse teams, BIPOC and other marginalized scholars are implicitly expected to outperform and overcontribute in their work. These same unreasonable expectations are not placed on scholars in the majority, even when their work or productivity is mediocre. In addition, it is often assumed that BIPOC and other marginalized scholars will lead diversity efforts without asking whether they are interested in taking on such roles.

These are significant problems across STEM fields. Research has shown that women and people of color must outperform men, especially white men, to achieve the same recognition or reward. Women in leadership roles are all too familiar with this phenomenon, facing heightened attention on their performance and expectations that their hiring would quickly translate into higher sales, improved company performance, or better science output. Along with the unfair performance standards women have long experienced, they have also faced harsher judgments for mistakes (*Coury et al., 2020*). *Pew Research Center* [2015] found that although gains have been made with more women in leadership roles, progress has been slowed by the dearth of higher expectations.

Fewer than 6% of STEM faculty in academic institutions are people of color, with *Watson* [2019] claims is because "faculty hire faculty." In other words, people hire people like themselves. If they do hire a person of color, they often must convince other faculty that the person has the right "pedigree" to be part of the institution. Once a person of color is hired, tokenism and isolation can set in because of heightened expectations for performance—which are reinforced by instrumental rationales for diversity—and because the person may well be one of only a few people of color in the department. *Watson* [2019] further suggests that faculty of color leave academia in search of fulfillment elsewhere because the academic environment is not welcoming and because the bias of the majority becomes especially apparent in recruitment and hiring practices. Of course, not retaining individuals who are outside the demographic majority defeats the goal of increasing institutional diversity.

Focusing on Equity over Expectations

We call for a new approach and a reframed rationale for DEIJ work in the geosciences, indicative of a commitment to creating institutional environments that are inherently equitable, where all members are heard, seen, and valued without having to provide justification for their inclusion. Institutions should make intentional efforts to recruit and retain people with a variety of backgrounds, experiences, and perspectives because they are seeking to be equitable, not because of the benefits these people are expected to bring to the institution.

To help with transitioning to an equity-focused approach, we recommend that institutions and individuals reflect on their reasons and motivations for supporting the recruitment and retention of a more diverse workforce and student body and how those motivations drive expectations of recruitment and retention. Words matter, so institutions should review their diversity and inclusion statements and update them to include moral rationales. Understanding and acknowledging the historic responsibility of an institution are often first steps. Land acknowledgments, for example, although performative as stand-alone actions, can be starting points for establishing authentic and equitable partnerships with Indigenous and local communities and can move institutions toward conducting science in more just and inclusive ways.

> Words matter, so institutions should review their diversity and inclusion statements

If your institution subscribes to the business case justification for diversity, question whether that approach creates inequitable or unrealistic expectations. Specifically, are there heightened expectations of new BIPOC hires? Are you expecting colleagues or students from BIPOC and other marginalized backgrounds to overperform? Do you have heightened expectations that hiring a few individuals will rapidly change the culture of the group? Are all students and colleagues allowed to be average at times?

Creating and nurturing a transformative culture require institutions to embody DEIJ as a foundational component to support their community and workforce. No institutions are doing this perfectly, but there are examples of institutions working toward transformational change. At Colorado State University, faculty performance reviews and tenure and promotion packages in many departments now include, as an evaluation component, evidence of incorporating DEIJ efforts into research, teaching, and service.

Positive and productive changes in institutions come with structural change at all levels, and these changes can take time. The benefits of diversity for science and for organizations are not immediate. They also do not depend only on the contributions of BIPOC and marginalized scholars and so won't be realized simply by augmenting numbers. Instead, the benefits come from systematically creating inclusive and equitable spaces that allow all scholars to be productive, to contribute, and to be valued and evaluated fairly.

It is time for institutions to create transformational and equitable cultures by recognizing everyone's humanity and no longer treating efforts in diversity, equity, inclusion, and justice as a business decision.

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Growing Equity in City Green Space

City residents don't all have the same access to the benefits of green space. Addressing this inequity requires community engagement at every stage from planning to development to management.

By Kimberly M. S. Carter

As the COVID-19 pandemic stretched on, people around the world began to flock to outdoor green spaces in and around cities. For some, safe and socially distanced relief from indoor lockdowns came from picnicking in nearby parks, while others found relief from mental illness, healing from strong trials through the mountains and forests, or simply getting fresh air in their backyards. However, not all city residents have the same access, geographically and psychologically to nearby green space.

That tumultuous time "put everything in really high relief about the importance of having a safe green space in every neighborhood," said Sharon J. Hall, who teaches the intersection of ecosystem management, environmental quality, and human well-being at Arizona State University (ASU) in Tempe. "We know that nature brings mental health benefits, physical benefits, spiritual and community connections, and all sorts of recreation benefits and cultural benefits, but not everyone has the same ease of access to it. There are populations that have really long distances to travel, sometimes through roads and what nature means to them."

Access to nearby urban green space—places covered with grass, trees, shrubs, or other vegetation—and infrastructure that works with it is a luxury in many cities these days. But experts agree that the solution is more complicated than simply planting more trees in certain spots. Done right, adding new green space in and around cities can improve human health, mitigate extreme heat events, and boost a region's economy. Done wrong, it can worsen existing socioeconomic and ecological problems or even create new ones.

> Experts agree that the solution is more complicated than simply planting more trees in certain spots.

Urban Forests Benefit City Residents

Green spaces in and around cities, collectively known as urban forests, can mitigate regional and local flooding from storms, reduce water scarcity, improve air and water quality, regulate temperature, and sol solution cycling, all while sequestering carbon.

Each tree in that forest is important. With all of their steel, concrete, and concrete, cities are typically a few degrees hotter than surrounding rural areas, and the difference is phenomenon known as the urban heat island effect. The same phenomenon occurs on a substrate scale to a degree that depends on a neighborhood's green space.

"Trees are a really important contributor to reducing heat in neighborhoods," explained Vivian Bell-Hoven, an urban hydrological scientist research is interested in environmental justice. She is a postdoctoral researcher at the National Socio-Environmental Synthesis Center in Annapolis, Md. "If the shades part of your home or much of your neighborhood, it's going to be cooler than neighborhoods where you don't have trees on the block at all."

Moreover, "there are cultural benefits of having green space in and around your neighborhood," said John Rick Poor, "for lower-income people, it's a place to relax, improve their well-being of people, and for creating spaces that are more livable and more accessible." Poor is the implementation manager of EcoWeeds, an international organization that helps cities conserve, manage, and restore their forests.

Combined, these ecosystem services "are the broader benefits of green spaces," said Ayushi Trivedi, a gender and social equity research analyst at the Nature Conservancy. "We have to have a socially equitable impact; they need to be distributed in a way that all communities derive benefits from them. This is especially important for vulnerable communities—marginalized communities, low-income populations, racial minority communities—that live in neighborhoods that are more exposed to heating, stormwater flooding, and pollution."

Where the Green Spaces Are

Environmental justice affirms that all people have the right to land, water, and air that are clean and safe; it requires environmental policy that is free from discrimination and bias and is fair and equal respect and justice to all people in assessing whether all residents of a city have equitable access to urban forests, the first question of interest is, Where does the city have green space? To tackle this on a citywide scale, most researchers either collect satellite or aerial imagery, which can measure down to only a certain scale, or conduct laborious on-the-ground surveys.

Because of the limitations of data collection methods, most studies that the distribution of urban green space focus on just one or two cities at a time, which can hinder analysis of nationwide trends. "The amount of work it takes to generate an urban forest cover map of a city is so much a possibility that to do something on a larger scale can be difficult," explained Brannon Lea Watkins, a public health researcher focused on health equity and the ecology of trees. "We know that the urban forest is different across the country because the ecosystem is different. So we would expect a different amount of tree canopy cover in Philadelphia than we would in Miami."

> "If you disaggregate by demographic or social characteristics, then you are able to see what the social inequities are."

Watkins and her colleagues aggregated many individual studies into meta-analyses which they combined data from both smaller and upwards forested U.S. cities. Trivedi said such methods can help researchers and city planners identify which groups benefit the most from an existing or planned green space. "What is their cost? Who does they live? What jurisdiction's they household composed of? If you disaggregate by demographic or social characteristics, then you are able to see what the social implications can be. Whether it is mapping or doing a statistical study, the overall act of disaggregating your data and then seeing the patterns that come up, will be very helpful in telling you what the gaps are, who is benefitting the most, who is impacted by the costs the most, and who is taking the most risks."

For instance, "in most studies there's a demonstrated pattern between income and urban forest cover; that is, higher income is associated with more urban forest cover," explained Watkins. What's more, across the nation, race-based inequity in urban forest cover is higher on public land than on private land, "which is a pattern we don't like."

Trivedi stresses a more collaborative approach to income and predominantly white neighborhoods, and the same is true to an even greater degree for public-housing units and historically redlined areas.

> "Historically redlined neighborhoods have less green space, and the green space that they have is also not as high quality."

The Type of Green Space Matters

After you know where the urban forests are, it's helpful to analyze what form they take, because not every type of green space provides nearby residents with the same benefits. However, who classified a recent paper that examines race and privilege in green space (U.S. urban green space and privilege), explained that "[historically] redlined neighborhoods have less green space, and the green space that they have is also not as high quality."

Parks, for example, look very different in urban areas that are more heavily polluted, which tend to be neighborhoods with more people of color, more frequently impervious people, or more people with lower incomes. "If a tree is blocking the line of sight for a police camera, for example, the tree gets cut down or drastically trimmed so that it's no longer effectively providing shade" and cooling the surrounding area.

> "Green spaces can generate pollution. … It's these in-between, accidental spaces that are sometimes the more vulnerable. It's what we think about green space."

In these neighborhoods, "parks aren't necessarily made to be places where people sit or relax," Hoven explained. "They are places to be passed through. I think that is also reflective of the way that housing insecure individuals are criminalized and the way that cities often respond to folks who are housing insecure by wanting to prevent their homeless from using or being able to lie down on a bench."

Vacant lots that have been renaturalized can contribute green space, said Theodore Lim, but the benefits of that space for the surrounding community are going to be far less strategic than the benefits of a planned park. "One is developed under conditions of growth and positive planning, and one is developed in conditions of decline and reactive planning," he explained. "You're left with a community that's ambivalent about where you can get ecosystem services. Cities sometimes connection between land, water, infrastructure, and people in sustainability planning at Virginia Polytechnic Institute and State University in Blacksburg.

"In cities, I think we need to be more expansive with how we think about green spaces," Hall said. "Green spaces can occur anywhere. … It these in-between, accidental spaces that are sometimes the more vulnerable. It's what we think about green space."

Whether practice or reaction, to benefit a community "urban green spaces should be planned on a case-by-case basis depending on the climate, the geography, the soil conditions, and the water-supply needs of that area," explained Chris Duvall, a water resources engineer and executive director at Climate-pedia. "In an agricultural setting, for example, a sustainable green space would likely rely on seasonal cycles of precipitation. In a drought-prone region, a green space might also consider how it will be irrigated."

"I was designing a green street for an area near the University of California, Los Angeles that incorporate sustainability concepts, stormwater capture concepts, and green space concepts," Duvall said. "That region has a lot of clay soil, and we meant that installing pervious pavement wasn't an option because water would just through the sidewalk but not into the soil. "But for other regions with sandier soil, where water is much more readily available, pervious pavement might be a way for a parking lot to capture stormwater on site."

"There are strategies for many different geographic scales," Duvall said, from rain barrels to bioswales and from rain gardens to watersheds.

Community Ownership Is Key

Green spaces should be intentionally designed to meet needs that the community has identified so that residents will be comfortable using them. Such a design strategy requires engagement and dialogue between communities and project managers.

"People theoretically may have the same amount of access to acres of park space but still may not feel welcome or safe in that park space," Lim said. "It's about recognizing that there are systemic issues that shape people's experiences and that those have real-world costs."

> "Nature-based solutions need to be treated like all other infrastructure and deserve the same participatory approach during planning stages."

"There are positive historical relationships to consider as well, she added. "You might think about Latina populations who are living in the Southwest, the desert might have a different sort of meaning to them if they have history with the desert through their families and through generations."

Many Detroit residents, for instance, expressed the belief that the city had neglected or mismanaged the green spaces and trees in their neighborhoods. Because of that historical precedent, people were distrustful when a local nonprofit offered them trees to plant in front of their houses. Despite a persuasive neighborhoods, a quarter of residents rejected the planting of new trees, anticipating that the city would neglect that green space.

"There's not going to be a one-size-fits-all approach" to creating urban green spaces for ensuring equity in those spaces, Hall said. "What's going to be good for pollinators or people, unfortunately, can be very different than what's going to work for Sonoran Desert in Phoenix, Ariz., versus what's going to work for Boston, versus what's going to work for Jasmar or Los Angeles. … Approaches are going to need to be locally determined, about what types of plants you're going to plant and what's going to be really good for the history of a community."

What Community-Driven Solutions Look Like

Let's say you're a geoscientist with an idea of how to improve an urban neighborhood by adding more green space, and you want the project to be a participatory process. How do you then get the community on board? "Nobody really trains you on how to be a community researcher. You learn by doing," said Marta Berbeo-Velazquez. "You scan the news, you scan

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Facebook, you start following activists in a region, you start figuring out who's who. That takes a little bit of time, and a lot of it is very subtle." Berbeo-Velázquez researches the human dimensions of coastal ecological transformations in rural and urban ecosystems as an assistant professor at ASU.

"I might go to a random community event," she continued. "I might go to a webinar or go to community meetings. And I would just sit in the background and listen and not talk." By doing so, a researcher learns what issues are at the forefront of a community's agenda, who key leaders are, what historical or systemic issues that community is facing.

After so many residents rejected free trees, for instance, the Detroit nonprofit shifted its approach to include communities in the decisionmaking process regarding the types of trees and where to plant them. It also expanded its youth employment program to maintain the trees and teach residents about them.

"I think the tendency is for geoscientists to focus on data analyses," Duong said, "and then point to them and say, 'this is what the data tell us, therefore you need to do this or that.' But wouldn't it be better if we actually asked the people who live in the neighborhood what types of plants you're going to plant and what's going to be really good for the history of a community?"

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Raising the Visibility of Latin American Science

Latin American scientists and journals are strengthening research, evaluation, publication, and communications systems to help redefine ideas of professional success that have been largely determined by the Global North.

By Humberto Basilio

J. Henry Fitzmaurice/Flickr

Graduating from a recognized university is a privilege in a world in which most don't have the financial means to achieve this. And building a "successful" scientific career is a challenge with added economic, structural, and language barriers.

Lina Pérez-Ángel knows the journey well. Her mother was the first woman in her family to migrate from Caparrapí, a small municipality in Colombia, to the capital city of Bogotá. And although Pérez-Ángel and her siblings were born and raised in the city, she remembers traveling to her mother's hometown—a place she identifies as her home, too—throughout her childhood. That rootedness in Caparrapí would lead to her interest in researching the paleoclimate of Colombia's Eastern Cordillera.

"I didn't grow up in that world of science and curiosity," said Pérez-Ángel, who originally wanted to become a chef but started her academic career studying engineering because her mother told her to. (She later found her real passion in the geosciences.)

As an undergraduate at Bogotá's Universidad de Los Andes, Pérez-Ángel noticed a pattern among the readings required for classes: No matter what subject she was studying, European and North American surnames dominated the literature. Much of the university's faculty also came from outside Colombia. Even among the Colombian professors, the most recognized had pursued their graduate degrees outside the country.

"You guys have to get out, get out of here to do science" was the most common advice Pérez-Ángel remembered getting from her professors.

That advice was informed by two trains of thought. The first was that countries in the Global North have more funding and better infrastructure to do science. The second was the widespread belief that learning about the world outside Colombia would give students new perspectives for their research.

Both ideas made sense to Pérez-Ángel at the time, but the constancy with which she heard them also made her feel pressured. "I came to have the idea that [staying in Colombia] was like a failure," Pérez-Ángel recalled. "Now I eat my words, but at that time it was something that remained in my subconscious...that if I wanted to become a [recognized] professor or researcher, I needed to leave."

> "It was something that remained in my subconscious...that if I wanted to become a [recognized] professor or researcher, I needed to leave."

Becoming more closely involved in the projects of her undergraduate professors allowed Pérez-Ángel to join the Smithsonian Tropical Research Institute in Panama. The connections she formed there opened the door to more opportunities. Eventually, she completed her Ph.D. in the geological sciences department at the University of Colorado Boulder and is now a postdoctoral research associate at Brown University.

Pérez-Ángel's career path isn't unusual among students at Latin American universities. Global visibility plays a significant role in establishing scientific careers, not only in terms of recognition but also in the effort to obtain funding, grants, and resources to continue doing science. The search for global visibility creates the pressure to study abroad.

However, seeking recognition in so-called "global science" implies accommodating the norms, ideas, and people who lead research activity in the world's hegemonic scientific institutions—those of the Global North.

Internationalization: A One-Way Street

In 2019, Argentinean researcher Magdalena Martínez, a Ph.D. candidate in higher education at the University of Toronto, became interested in the ways that international engagement informs the research activity of highly cited Brazilian scientists. In other words, she analyzed the extent to which connections, academic exchanges, graduate studies, and international collaborations may have enhanced the researchers' careers.

To identify the most highly cited Brazilian scientists, Martínez and her team turned to the annual list of the entire world's most highly cited scientists, published by Clarivate every year since 2015. These lists derive from Web of Science–related databases and metrics, which serve to identify scientists who have "demonstrated significant and broad influence in their chosen field of research," according to Clarivate.

Among the 4,058 most cited researchers worldwide in 2018, 65% were from the United States, 13% were from the United Kingdom, and 13% were from China. "Unsurprisingly," authors pointed out, scientists affiliated with British universities occupied a more marginal position than their Western and Chinese peers—just nine of the 4,058, or less than one quarter of 1%.

Martínez and her team looked at more than 1,500 papers to analyze their date of publication, citations, and type of authorship and collaboration, as well as the countries where collaborating authors lived. Authors' curricula vitae were also analyzed.

The team found that of the nine highly cited Brazilian authors, almost all were involved in global research networks. Eight of the nine had 1- to 10-year international experiences, mainly in the United States and Europe. Those experiences and connections (mostly established early in the scientists' careers), Martínez said, were crucial to the researchers' success.

Other studies have analyzed the citation patterns of researchers from Latin America who don't copublish with peers from developed countries in recognized journals. Generally, when authors publish without global visibility, they are under-cited. One group of researchers readily acknowledged that scientific research visibility benefits from collaboration. However, they write, whether under-citation is due to a "psycho-social bias or real differences in scientific relevance of these articles" remains a concern.

Collaboration and Visibility

The degree of global visibility often depends on the study area in question, said atmospheric physicist Paulo Artaxo, one of the most cited Brazilian authors of 2018. For instance, he explained, environmental science combines different research areas and benefits from multiple partnerships. "Without collaboration," Artaxo said, "forget about it...you cannot do much."

Artaxo ventured into global science 40 years ago when he studied the effects of biomass burning in the Amazon with the Dutch atmospheric chemist Paul Joef Crutzen, now deceased. Later, Crutzen invited him to the Max Planck Institute for Chemistry in Mainz, Germany, where Artaxo began networking with renowned scientists from around the world.

"I was lucky to be in the right area in the right moment," said Artaxo, now affiliated with the Universidade de São Paulo. "The number of citations of my papers reflects that."

While emphasizing that citation is by no means the determining factor of the quality of research, Artaxo noted that global visibility is the main reward of publishing in highly ranked journals. As of 2022, no journal published in Latin America appeared in lists of the world's publications with the highest impact factors; Latin American journals are more vulnerable to economic conditions and even closure. Spending years of work on research only to publish in a journal that will "die quickly" because it has no readership, Artaxo said, is a "waste of time, money, and everything."

Latin America's Struggle for Visibility

Western science has established itself as the world's epistemic authority. It determines which science is the "best" through its evaluation model, and it determines the right people to evaluate. Thus, "Global North journals are the gatekeepers of... research 'quality,'" said Hebe Vessuri, an Argentinean social anthropologist at the Environmental Geography Research Centre (CIGA) of the Universidad Nacional Autónoma de México.

Latin American institutions have largely adopted the same citation-based evaluation parameters as the Global North: If researchers want a high score, they need to publish in journals with a high impact factor—as determined by the traditional standards of the Global North. Publishing in these journals involves developing research within the limits of the Global North's interests. In most cases, local science is not part of that scope.

The prevailing citation-based evaluation model has been criticized for years. In 2012, during the annual meeting of the American Society for Cell Biology, editors of academic journals from around the world drafted a series of recommendations to improve evaluation practices at funding agencies, institutions, and other organizations.

The so-called San Francisco Declaration on Research Assessment pointed out the need to eliminate the use of journal impact factors as the basis for funding and consideration for professional advancement. Signatories stressed the necessity to assess research on its own merits rather than on the basis of the journal in which the research was published.

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Still, finding an effective way to solve the problem is much more complex than a thoughtful declaration.

Concentrating such power in publications in the Global North has caused scientists to lose interest in publishing in national or regional journals in Latin America. (Sometimes countries lose researchers themselves as the region grapples with brain drain to the Global North.)

The professional standing of these journals, where most regional scientific research is published, has also worsened due to economic and political crises. Latin America has one of the lowest investment rates in research and development, and that investment is not evenly distributed: Argentina, Brazil, and Mexico account for 85% of total scientific investment across Latin America.

For Vessuri, there is a delicate balance between the importance of international training for young scientists and retaining scientists for national research. Those who leave often do not return, and those who stay often prioritize producing research valuable to the Global North, Vessuri said. "It is an intellectual crisis of nation-states...they become mere appendages of the international system."

This problem has existed for decades and "continues practically unchanged," said Claudia Amescua, head of the editorial section of the Institute of Atmospheric Sciences and Climate Change of the Universidad Nacional Autónoma de México.

For Amescua, the issue originates not only with the dominance of the evaluation model of the Global North but also with the earliest stages of Latin American researchers' education. "It is the vision of how the scientist should be, the importance of prestige, the importance of where to publish," he said. This is the stage at which Pérez-Ángel felt the pressure to leave Colombia.

Following this vision, researchers can isolate themselves from Latin America because they are in "another world," Amescua said. Until the region's science policy encourages national research and publication, however, little or nothing will change, he admitted. "That's not to say that each world should function independently," he said, "but that they should function interlinked."

The Latin American Model

Unlike the private, high-impact journals of the Global North, most Latin American journals have historically been produced by public universities. Their financing depends not on authors or subscriptions but on the resources that federal governments provide to educational institutions. The "Latin American model," as Amescua described it, had an open access operation even before the concept was formalized 20 years ago.

This story is also available in Spanish, Portuguese, and French

In the beginning, Latin American journals functioned as a way to disseminate the research of scientists at individual schools. Adopting evaluation parameters led journals to formalize their structures and become internationally competitive.

Fed up with the fact that Latin American publications remained "gray literature" compared with journals from the Global North, physicist Ana María Cetto oversaw the entry of *Revista Mexicana de Física*, a physical science journal, into the Science Citation Index Expanded.

Even after taking this "big step," Cetto sought to strengthen the visibility and exchange of knowledge among the nations of Latin America as well as with those outside it. Cetto started discussing the issue with people from the International Council for Science and UNESCO (United Nations Educational, Scientific and Cultural Organization), with whom she worked at the time. "Stop complaining and do something about it," Cetto remembered getting as a response. And so she did.

Cetto and a group of Latin American scientists and editors launched the Regional Online Information System for Scientific Journals of Latin America, the Caribbean, Spain, and Portugal (LATINDEX), a bibliographic information system that seeks to address Latin America's underrepresentation in indexes and databases produced in the Global North.

Latin American journals "are a communication vehicle for a community of younger scientists. It's where they can have access to knowledge without having to pay or without having to belong to an institution."

Today scientists in 23 Spanish- and Portuguese-speaking countries gather and disseminate information in LATINDEX, as well as in other regional databases for scientific publishing such as Redalyc and SciELO.

The creation of these initiatives is crucial to strengthening regional science and the progress of science education, Cetto said. "The [national] journals are a communication vehicle for a community of younger scientists. It's where they can have access to knowledge without having to pay or without having to belong to an institution. It's where they can learn to publish, train as referees, and establish contacts with other members of the community."

Although these projects have undoubtedly helped increase the visibility of regional journals, the relative lack of resources affects even already well-positioned publications. For instance, the Mexican journal *Revista Internacional de Contaminación Ambiental*, where Amescua has served as managing editor for 15 years, has had to negotiate collaboration agreements with other Mexican universities. "We work with teams of just a few people…the luckiest ones don't reach four people hired full-time," said Amescua.

In recent years, public universities throughout Latin America have invested in subscription packages so their scientists can access and publish in high-impact journals from the Global North.

Amescua believes financial resources should also be invested in regional journals.

"We ran out of funding," said Karenia Córdova, who helped lead the *Terra* geography journal at the Universidad Central de Venezuela. *Terra* achieved important visibility among Venezuelan and foreign scientists, but in 2021 it published its final issue due to a lack of resources.

Córdova said the problems facing *Terra* were shared by other regional publications. They started with not being able to afford and maintain the DOI (digital object identifier) system necessary to remain in academic databases and included not having web editors or other necessary staff to publish the journal consistently. (When the publication folded, Córdova was *Terra*'s only full-time employee.) These infrastructure challenges result in a fall in a journal's impact rankings, Córdova said, which perpetuates the inequitable system by discouraging scientists' interest in publishing there.

Terra was part of a boom of Venezuelan journals in the late 1990s, a time when the nation experienced renewed investment in regional science and art. However, political and economic conflict compounded, and this effort gradually lost strength and funding. The crisis at *Terra* was part of larger budget cuts to universities in the country. Over the past 8 years, the number of registered journals in Venezuela decreased from 41 to 31 in the citation database Scopus.

The decline of investment in regional journals also meant a loss of national scientific production, said Córdova. Researchers in Venezuela have consistently published fewer articles every year since 2009, she said, and as of late 2022, the country had dropped from 50 to 70 among those ranked in Scopus.

For Córdova, internationalization is necessary to maintain the interest of researchers. But to make national and regional scientific production grow in parallel, it is essential to strengthen those journals' accreditation.

Low quartile (Q) indicators—which serve to evaluate the relative importance of a journal within the total number of journals in its field—also have repercussions for regional collaborations. (Q1 journals are considered most important.)

"Each article published in a Q4 journal plays against my certification of adviser of doctoral programs and grant competitions," said José Arumí, a researcher at the Center for Water Resources for Agriculture and Mining at the Universidad de Concepción, in Chile. "Therefore, I stop[ped] sending articles to *Tecnología y Ciencias del Agua*, which is a Mexican journal that publishes in Spanish, with which I have a long history and [for which I have] great affection," he said.

The Language of Science

Even before *Terra* ceased publication, the journal was forced to cut its Spanish-to-English translator. Córdova herself began to translate at least the titles and abstracts of the papers in *Terra* to expand its reach. "A title in Spanish has a third of the visibility that it has if you publish in English in any journal," she said.

English is the lingua franca of science. Of course, having a common language to share knowledge and create networks is an advantage in scientific progress and communication. However, the prevalence of English in a context already dominated by the Global North further perpetuates a cultural hegemony.

English is the lingua franca of science.

Latin American scientists have pointed out that this hegemony has manifested a dangerous idea among communities both within and outside the Global North: What is written in English is of higher quality than that which is written in Spanish or Portuguese. "Publishing in English is not the problem," however, explained Pedro Urquijo, a researcher in Latin American historical geography at CIGA. Instead, he said, belonging to a system that forces researchers to produce for English-speaking journals just to earn points and obtain high ratings no matter whether their community can read them: "That's the problem."

English is the native tongue of just slightly more than one third of the 1.5 billion people who speak it globally. In Latin America, it is no secret that learning English is a privilege, and many renowned public universities promote teaching English. The proficiency level obtained, however, could be not enough to face the English-speaking world, researchers said, especially in scientific careers.

"When I came to the U.S., I thought I knew English, but I didn't," said Pérez-Ángel. In fact, language was one of her biggest hurdles while completing her Ph.D. Living through that experience made Pérez-Ángel much more conscious of the limits brought about by placing a priority on English. At one point, she attended a conference in which the speakers discussed the lack of data on a Colombia-specific paleoclimate issue, and her patience reached its limit. "[The information] does exist, but it is written in Spanish and not published in a Northern journal," Pérez-Ángel said.

The Science of the Future

Scientific knowledge is obviously not universally accessible, said Pérez-Ángel. According to the Organization of Ibero-American States for Education, Science and Culture, only 1% of all articles published in scientific journals in 2020 were written in Spanish or Portuguese, compared with 95% in English.

But Pérez-Ángel, along with other Colombian geoscientists, is trying to change that.

While chatting on the bus ride home from a field internship in 2014, Pérez-Ángel and Carolina Ortiz, a geologist at the University of Florida, decided to start a project to share what they were learning with their friends, colleagues, and family. What began as an Instagram account where they shared photos eventually transformed into a science communication initiative that aimed to spread geoscience research in Spanish to the public as well as their scientific peers.

After their experiences abroad, Pérez-Ángel, Ortiz, and Daniela Muñoz-Granados (now a geologist at the Servicio Geológico Colombiano) realized that the project could generate more outreach and be more useful if they took advantage of their bilingual capabilities. Thus, GeoLchat (a name chosen to be understood in both English and Spanish) was formalized across a website and social media platforms. GeoLchat allowed the scientists to create a community that could share and learn by breaking down the language barrier. "You have to create bridges where there are none," Pérez-Ángel said.

By creating and translating interactive content, as well as by fostering discussion spaces, GeoLchat has grown a diverse community interested in the Earth sciences. One of GeoLchat's most popular spaces, the YouTube series La Pola Geológica (The Geological Beer), has brought together researchers from Chile, Colombia, Cuba, Mexico, Puerto Rico, and Venezuela to share their research and generate discussions with Spanish- and English-speaking audiences. Such opportunities strengthen the Latin American community and provide peers from the Global North with an open platform to get to know the science that is being produced in Spanish.

"It's a way to show that many other things are going on that they [scientists and institutions of the Global North] do not realize because it isn't within their comfortable reach due to the language," Pérez-Ángel said. "Science is done with the same quality in many other places, but they don't see it because they are on the side of privilege, not on the side of those of us who have had to learn another language to be able to communicate."

GeoLchat is part of a much larger community supporting the idea that it's crucial to maintain Spanish-written research. LATINDEX, for instance, considers multilingualism a "matter of principle." Its databases accept journals from all over Latin America, but one of the quality criteria that gives the best scores is including abstracts of the articles in Spanish or Portuguese and another language.

"There are magazines in Latin America that have decided to no longer include even that [the abstract] in their mother tongues," said Cetto. "We want to induce them to adopt good practices that are favorable for the region.... It would be very unfair that a language that is spoken by almost 500 million people [such as Spanish] does not have its own spaces for publication."

Keeping Spanish and Portuguese as living scientific languages is also one of the goals sought by many academic journals throughout the region, said Amescua. However, the entire Latin American publishing and communication model must be strengthened, he contended, "making it grow based on its own characteristics, being congruent with its history, with its social development, and with its needs to remain as a valid peer of the North, and not as a favors requestor."

Global visibility ultimately manifests in different ways. Looking back on how she developed her career, for instance, Pérez-Ángel realized that being outside Colombia helped her to be more confident that she will use everything she has learned to continue studying the place where she grew up. Working on Colombia-focused research with her peers in Colorado, Pérez-Ángel said, has given her new insights, learning, and perspectives. But it also made her aware that the deep knowledge she has about Colombia's climate, geography, and people is irreplaceable.

For many Latin American scientists, there is only one way forward: to engage all parties in an equitable, inclusive, and diverse manner. "That is the real science of the future," said Pérez-Ángel.

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