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ORIGINAL PAPER

Climate action in cities and the lifelong learning nexus: Results of an international assessment

Walter Leal Filho[1,2] · Yusuf A. Aina[3] · Luciana Brandli[4] · Johannes M. Luetz[5,6,7] · Roberto Schoproni Bichueti[8] · Bruno Borsari[9] · Ricardo Luiz Fernandes Bella[10] · Abdulaziz I. Almulhim[11] · Edward Mendy[12]

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Abstract
The need for cities to engage in climate action stems from a combination of factors that comprise both their contribution to climate change and their critical role in mitigating its effects. Cities are subject to the direct impacts of climate change, including rising sea levels, more frequent extreme weather events, heatwaves and urban heat island effects. These threaten infrastructure, economies and livelihoods, necessitating robust climate resilience and adaptation strategies. Learning initiatives that support climate action are urgently needed to address climate change in cities. This article presents an international evaluation of the learning tools used to support climate action in cities. This assessment is underpinned by lifelong learning theory. Using a case study approach, involving 34 cities around the world, this study describes the means deployed to promote climate action and the learning outcomes associated with them.

Keywords climate change · citizen – education · lifelong learning · extreme weather events · climate change education

Résumé
L'action climatique dans les villes et son interconnexion avec l'apprentissage tout au long de la vie : résultats d'une évaluation internationale – La nécessité pour les villes de s'engager dans l'action climatique découle d'un ensemble de facteurs, qui comprend à la fois leur contribution au changement climatique et leur rôle crucial pour en atténuer les effets. Les villes sont directement touchées par le changement climatique, notamment par la montée du niveau de la mer, la multiplication des épisodes météorologiques extrêmes, les vagues de chaleur et les îlots de chaleur urbains. Ces phénomènes menacent en effet les infrastructures, les économies et les moyens de subsistance, et rendent indispensable la mise en place de stratégies solides de ré-

Extended author information available on the last page of the article

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silience et d’adaptation climatiques. Il devient urgent de mettre en place des projets d’apprentissage soutenant l’action climatique pour relever les défis du changement climatique dans les villes. Le présent article expose une évaluation internationale des outils d’apprentissage utilisés pour soutenir l’action climatique dans les villes. Cette évaluation repose sur la théorie de l’apprentissage tout au long de la vie. Adoptant une approche basée sur des études de cas, concernant 34 villes à travers le monde, l’étude décrit les moyens mis en œuvre pour promouvoir l’action climatique et les résultats d’apprentissage dont elle s’accompagne.

العمل المناخي في المدن وعلاقته بالتعلّم مدى الحياة: نتائج تقييم دولي

الملخص:

تنبع الحاجة إلى انخراط المدن في العمل المناخي من مجموعة من العوامل التي تشمل إسهامها في تغير المناخ، إلى جانب دورها المحوري في الحد من آثاره. وتتعرض المدن بصورة مباشرة لتأثيرات تغير المناخ، بما في ذلك ارتفاع مستويات الحرارة، وتزايد تواتر الظواهر الجوية المتطرفة، وموجات الحر، وظاهرة الجزر الحرارية الحضرية. وتشكل هذه التأثيرات تهديدًا للبنية التحتية والاقتصادات وسبل العيش، مما يستدعي تبني استراتيجيات فعّالة لتعزيز القدرة على الصمود والتكيف مع تغير المناخ. ويُعد التخطيط للمبادرات الداعمة للعمل المناخي أمرًا ملحًا لمواجهة تحديات تغير المناخ في المدن. وتقدم هذه المقالة تقييمًا دوليًا لأدوات التعلّم المستخدمة لدعم العمل المناخي في المدن. وتستند الدراسة إلى نظرية التعلّم مدى الحياة، وتعتمد منهج دراسة الحالة، وتشمل 34 مدينة من مختلف أنحاء العالم، كما تستعرض الوسائل المستخدمة لتعزيز العمل المناخي، إلى جانب نواتج التعلّم المرتبطة بها.

Introduction

Roughly half of the world’s population currently lives in cities. Francesco Orsini et al. (2013) have indicated that, by 2050, this proportion could reach as much as 70 per cent. Thus, cities occupy a critical position in the fight against climate change because they are home to most of the world’s population, are responsible for 70 per cent of global greenhouse gas emissions, and are in themselves highly vulnerable to the effects of climate change (Wei and Chen 2021).

Between 2011 and 2020, average global temperatures increased by 1.1 °C. According to the International Panel on Climate Change, by the end of the century this increase could reach 3.2 °C (IPCC 2023). The speed of increase depends largely on global efforts to mitigate climate change impacts and the success of attempts to reduce greenhouse gas emissions (Collins et al. 2013).

According to the C40 Cities group (a global network of the world’s largest cities committed to addressing climate change-related challenges),[1] 70 per cent of cities are already affected by climate change, of which about 90 per cent are located in coastal regions, which puts them at risk from rising sea levels and extreme storms (UCCRN 2018). Climate change exposes cities to unpredictable shifts in the frequency and intensity of storms, fluctuations in precipitation

[1] For more information, visit https://www.c40.org/about-c40/ [accessed 24 June 2026].

patterns and average temperatures, posing great risks to human life (Bulti et al. 2021). Also, more frequent and extreme weather events increase the risk of landslides and flash floods (Kumar 2021). Increasing sea levels can escalate risk exposure to housing and infrastructure in coastal zones (Kekeh et al. 2020).

The urban heat island effect is a further phenomenon observed in cities, where built-up areas become warmer than their rural surroundings. Climate change exacerbates this effect, leading to more frequent and intense heatwaves (Karimi et al. 2023). High temperatures can strain energy systems due to increased demand for cooling, leading to health problems such as heatstroke (Singh et al. 2020). Additionally, urban infrastructure, including transportation, energy and waste management, is highly vulnerable to the impacts of climate change. Extreme weather can damage roads, bridges and public transportation, disrupt power supplies and overwhelm drainage systems (Salimi and Al-Ghamdi 2020). The economic costs of repairing or replacing infrastructure, along with lost productivity under these circumstances, can be immense (Hobbie and Grimm 2020).

Climate change also amplifies social inequalities in cities, disproportionately exposing vulnerable populations such as the elderly, children and low-income communities to heatwaves, pollution and natural disasters (Marshall et al. 2020). The health impacts from such events range from acute injuries to long-term, chronic diseases (Ebi et al. 2021). It is also worth noting that greenhouse gas emissions are often concomitant with air pollution, which has a severe impact on human health (Wang et al. 2020). According to a World Health Organisation report, nine out of ten people worldwide breathe contaminated air (WHO 2018). Moreover, extreme changes in temperature, relative humidity, precipitation and wind can have detrimental effects on cities' cultural heritage assets (Sesana et al. 2021).

Overall, climate change poses multiple severe threats to human and planetary health, disrupting ecosystems and amplifying environmental degradation. Rising global temperatures intensify extreme weather events – such as hurricanes, wildfires and droughts – while accelerating ice melt and sea-level rises endanger coastal habitats and biodiversity. Ocean acidification, driven by increased CO^2 absorption, devastates marine life, particularly coral reefs and fisheries that sustain complex food chains. Shifting climate zones force species to migrate or face extinction, reducing genetic diversity and further destabilising ecosystems. These interconnected impacts weaken the Earth's resilience, threatening the ability of ecosystems to sustain themselves in their current forms.

In recent years, the term "resilience" has been increasingly used in academic and policy discussions in relation to the impacts of climate change in urban contexts (Amirzadeh et al. 2022; Ribeiro and Gonçalves 2019; Almulhim and Cobbinah 2024). Robin Leichenko (2011) posited that, in addition to promoting urban sustainability, cities must become resilient to a wider range of stresses in order to cope with climate change. Resilience refers to the ability of urban systems to maintain or rapidly return to desired functions despite disturbances (Meerow et al. 2016; Almulhim and Cobbinah 2024). It is also associated with the ability of cities to recover and maintain the conditions needed for living, commerce, industry, government and social gathering, despite calamities and other hazards (Hamilton 2009).

Adaptation strategies focus on enhancing cities' resilience while reducing the number and magnitude of risks (Hess et al. 2012; Solecki et al. 2011). Adaptation to climate change is particularly crucial, as this can increase resilience and enable sustainable development (Revi et al. 2014; Carter et al. 2015; Lu et al. 2021; Waters and Adger 2017). This challenge is more pronounced in developing countries (Bossio et al. 2019; Vajjarapu et al. 2019), where greater investment in low-carbon and climate-resilient infrastructure is needed to grow urban economies while addressing inequalities (Leal Filho et al. 2019).

Combating climate change in cities requires learning new strategies to support climate action and knowledge transfer (Granderson 2017; Olazabal et al. 2018) while pursuing social advances, including nature-based solutions (Frantzeskaki 2019). Such efforts provide input for future urban policies and planning (Pelling et al. 2022; Shi 2021). Knowledge acquired in cities resides principally in two domains: hard data stored in infrastructures, documents, computers or specialised units of government; and soft data stored in citizens' groups and community networks (Campbell 2009). Hence, an important task is to integrate urban knowledge and experience into multidimensional, multi-scale units, guiding adaptive responses to climate change and blending them into sustainable development strategies (Sanchez-Rodriguez 2009). The climate crisis demands a commitment to lifelong learning as a cornerstone of effective climate action. Individuals and communities must update their understanding to adapt and innovate as scientific knowledge advances, policies shift and new technologies emerge. Lifelong learning fosters climate literacy, empowering people to make more informed decisions – from adopting sustainable lifestyles to advocating for systemic change (Kolenatý et al. 2022). It enables the integration of climate-smart practices into various fields, such as agriculture, energy and urban planning. By supporting a culture of never-ending education through workshops, digital platforms and community engagement, societies can build the adaptive capacity necessary to tackle climate challenges. Thus, lifelong learning becomes not just an educational pursuit, but also a vital driver of collective climate solutions.

This article investigates the learning tools used to support climate action in cities. Through a multi-case study methodology, we identify distinctive approaches developed and employed by 34 cities worldwide to promote climate action. Our analysis of their learning and experiences may help other cities develop similar policies and approaches.

The need for climate change learning in cities

The need for climate change learning in cities is growing as they continue to expand while facing growing environmental challenges. Urban centres are significant contributors to greenhouse gas emissions due to high concentrations of people, industry and transportation. Although cities cover only three per cent of the world's landmass, they consume around 75 per cent of global energy resources and are responsible for between 71 and 76 per cent of CO^2 emissions (UN DESA 2019).

Cities stand on the front lines of climate change impacts, including extreme heatwaves and flooding, making climate change learning in urban settings essential.

Isabelle Anguelovski et al. (2014) suggest that awareness-building and climate adaptation can promote policies and plans that enhance the resilience of cities. According to Hans Dieleman (2013), a city's resilience depends on three dimensions: its physical infrastructure and technology; multilevel governance; and its innovative capacity, including the level of inclusion of marginalised groups. Exchanges between cities, study visits and active participation in adaptation policy networks encourage learning, enhance the credibility of policies, and serve as instruments for mentoring cities in their efforts to become more successful (Haupt 2021). The resilience of social-ecological systems depends on their degree of self-organisation and capacity for adaptive learning while nurturing diversity and generating constructive feedback for cities' economic, social and infrastructural domains (Tidball and Krasny 2007).

Learning networks become prominent actors in supporting local climate change adaptation by sharing best practices and lessons learned (Woodruff 2018). The C40 Cities network, for example, facilitates trans-municipal learning through a multi-stakeholder governing body, shared culture, and climate-change policymaking (Lee and van de Meene 2012). Interconnected networks of individuals, organisations and digital platforms facilitate the exchange of knowledge, resources and expertise to enhance collective and individual learning (Borland and Haken 1993). Moreover, they leverage collaboration, technology and shared goals to create adaptive learning environments, enabling participants to access up-to-date information, solve complex problems and innovate through continuous interaction (Perlman et al. 2025). By superseding traditional silos of education, learning networks foster lifelong skills development, cross-disciplinary insights and scalable solutions, particularly in dynamic fields like climate change, which demands agile knowledge dissemination. Irrespective of whether learning networks are formal (e.g., institutions, city networks) or informal (e.g., communities, social media), they empower stakeholders to learn, adapt and act in rapidly changing contexts.

There is, by now, a wealth of literature on initiatives undertaken to increase climate awareness and motivate urban populations to contribute to climate action. Mark Groulx et al. (2017) examined 64 articles that juxtaposed climate change intersectionality with citizen science. Most of these papers analysed existing or purposively collected data, which suggests that promoting empowerment, contribution to science, and insight into our own values and interests helps us understand different worldviews leading to collective action (Leitold et al. 2021). Charlotte Heinzlef et al. (2024) created a game that also serves as a decision-making tool to explain the need for long-term approaches in a municipality at risk of flooding. Marina Hofmann et al. (2015) examined the impact of sense-making on urban climate policies across three major German cities, showing how beliefs, ideas and knowledge influence strategies against climate change. Similarly, the findings of Antonio García Vinuesa et al. (2022) suggest that decision-making is influenced by knowledge processing within a frame of reference, indicating that the latter aids in understanding policy choices and evaluating their effectiveness. Johnathan Silver et al. (2013) found that understanding local economic and social contexts is crucial for effective climate change initiatives because primary activities like fishing and agriculture are more vulnerable to climate change impacts, while Oluyemisi Adebisi-Adelani and Mercy Akeredolu (2020) stress the significance of addressing climate change governance in urban areas and the need to develop innovative institutional structures. Cities are becoming the new focus of climate change action, as exemplified by Johannesburg in South Africa, where (political) power differentials are entrenched, necessitating a detailed vulnerability assessment procedure for more evaluation studies focusing on socioeconomic, socio-cultural and biophysical hazards (Vogel et al. 2021).

In March 2018, the Cities and Climate Change Science Conference took place in Edmonton, Canada (UN-Habitat 2018). There, a Global Research and Action Agenda on Cities and Climate Change Science was established to identify research priorities for local-level action (Solecki et al. 2021).[2] This conference also served to reveal major power differentials in governance (Hunter et al. 2022, 2023).

According to Anna Steynor et al. (2020), individuals consulted in each city perceived climate change as an issue close at hand, emphasising its urgency and importance. For example, rapid urbanisation in Asia has led to the emergence of new cities that are highly vulnerable to the effects of climate change. Low-income residents are constrained in their adaptive abilities to a changing climate, thus raising concerns about climate justice (Perlman and O'Meara Sheehan 2007; Button et al. 2013).

Climate change impacts in Africa are of significant concern, yet perceptions of their importance vary widely among individuals (IPCC 2014). A crucial factor that influences this perception is psychological distance; namely, the perceived proximity or remoteness of the risk in temporal, spatial, social and hypothetical terms (Spence et al. 2012).

Cities in Asia face similar challenges as growing climate hazards and rapid urbanisation stress local governments. The COVID-19 pandemic challenged many traditional principles of urban planning, which have shaped cities for over a century, despite valuable experiences that were generated by looking into how cities can confront climate change. Christina Kakderi et al. (2021) proposed a connected intelligence approach for addressing urban health and climate change crises, integrating human, collective and machine intelligence. However, Nicos Komninos et al. (2021) cautioned that this approach must be matched to appropriate technologies.

Methods

Adaptation to climate change in cities is a complex task, demanding actions at various levels (Victor and Salt 1994). It is essential to document and promote learning experiences on climate change in cities (Reichel and Haupt 2022). Our research relied on a thorough analysis of a large sample of case studies ($N = 34$) from selected urban environments (see Figure 1). The knowledge thus gained optimised our data analysis, enhancing the precision of the conclusions derived from this report. The criteria applied in selecting the cities included the following: regional representation, population size, existence of a successful experience of climate change learning, and relevant documentation in the literature. Another factor determining our choice of cities was the

[2] The Global Research and Action Agenda on Cities and Climate Change Science (GRAA) has since been updated; see Jance et al. (2024).

Fig. 1 World map showing the countries from which the 34 case studies originated

need to cater for different types and settings. Here, the priority was broad rather than balanced representation.

We adopted criteria for city size classification similar to those proposed by the Organisation for Economic Cooperation and Development (OECD 2022). Accordingly, we classified cities with a population of 1.5 million or more as "very large," those with a population between 500,000 and 1.5 million as "large", and those with a population between 200,000 and 500,000 people as "medium-sized". We collected the data through a literature review of peer-reviewed sources. This was important as a quality control measure since the case studies had been analysed previously, and their validity verified.

Case-study research is an accurate, investigative strategy that gathers data from a variety of sources, thereby generating new knowledge (Zahle 2019). It has become a well-established research approach in the social sciences (Widner et al. 2022). According to Adriana Takahashi and Luis Araujo (2020), there are robust, epistemological arguments for using case studies as a research methodology. In addition to reporting details about specific contexts, case studies support the comprehensive investigation of complex topics.

Our case study approach is fully in line with the study's purpose, which was to provide examples of how cities approach climate change education in the context of lifelong learning. Other types of studies, such as longitudinal studies or surveys, would be less suitable in this context. The tables we have compiled for this article (Tables 1, 2, 3, 4, 5 and 6) introduce a set of case studies ($N = 34$) that reveal learning experiences in cities in all six world regions, providing valuable insights and showcasing strategies for other municipalities to adopt and adapt in their efforts to better cope with climate change and the uncertainties it brings.

Table 1 Africa and the Middle East

City/Country	Population	Learning experience	References
Abu Dhabi, United Arab Emirates (UAE)	1.619 million (Metro Area)*	A paperless day initiative was implemented by the Environmental Agency in UAE to raise awareness about the climate change impacts of paper consumption and to help reduce the use of paper.	Menhali & Ahmed (2014)
Accra, Ghana	5.593 million**	Applying planners' perspectives on urban resilience can initiate strategies for absorbing disturbances (e.g., floods, rapid population growth, slum development) while retaining the city's identity, structure and functionality.	Cobbinah and Poku-Boansi (2018)
Cairo, Egypt	25.566 million**	Interviews with homeowners and observational walks at vulnerable sites (i.e., social housing, informal areas and historic residential areas) revealed that adaptations can differ without government intervention. Some adaptive strategies can be promoted as sustainable, nature-based adaptations and learning, applicable to more cities.	Dabaieh et al. (2024)
Dammam, Saudi Arabia	1.376 million (Metro Area)***	A debate learning strategy can be useful for sharing knowledge about issues such as climate change with female postgraduate students. Debates provide a good learning experience.	Alghamdi Hamdan & Aldossari (2021)
Lagos, Nigeria	12.792 million**	Awareness-raising programmes through capacity-building initiatives and summits are useful to address climate change. The latter targeted school children to teach them about waste management and energy use while capacity-building programmes targeted government staff and other stakeholders.	Elias and Omojola (2015)
Nairobi, Kenya	6.134 million**	Climate literacy focuses on community structures that leverage local knowledge. This includes digital storytelling, comics, art, music and local radio stations. Children play an important role in transformative climate resilience because they may comprehend climate change implications better than adults, increasing the possibilities for human behavioural change.	Muchiri et al. (2022)

Table 1 (continued)

City/Country	Population	Learning experience	References
Tehran, Iran	9.175 million**	Factors such as governance, awareness, education and knowledge, economics, communication and interaction are identified as potential constraints on climate change adaptation. Strategies to overcome these restraints can provide decision-makers with knowledge and learning about developing approaches for climate change adjustments in Tehran.	Ghasemzadeh & Sharifi (2020)

Note: Population figures *Macrotrends 2025a, **UN DESA (2025), ***Macrotrends (2025b)

Table 2 North America (United States and Canada)

City/Country	Population	Learning experience	References
Chicago, Illinois, United States of America (USA)	2.732 million*	Cities suffer from subsurface heat, which affects the environment, public health and transportation. In Chicago, a computer model informed by data collected via a network of temperature sensors is used to study changes in ground temperature, deformations. and displacements caused by climate change.	Rotta Loria (2023)
Houston, Texas, USA	2.397 million*	A household survey identified financial barriers to the use of home air conditioners in Houston, where large numbers of participants reported symptoms of heat stress. Heat mitigation and climate adaptation strategies must include adaptive technological, behavioural and community options.	Hayden et al. (2017)
Montreal, Quebec, Canada	4.292 million (Montreal Metro)**	Replacing all urban surfaces with low vegetation increased human comfort and lowered the heat index at night, whereas increasing the albedo (reflectivity) of urban surfaces improved comfort during daytime. This lesson can be applied world-wide.	Lauer et al. (2023)
Vancouver, British Columbia, Canada	2.6 million (Greater Vancouver)**	Flood resilience can be improved through the use of a simulation tool (FRST). The simulation model focuses on the impacts of riverine flooding and sea-level rise. Simulation results indicate that various factors (e.g., access to emergency funding, mobile hospital services, managed retreat) can boost resilience to flooding.	Simonovic & Peck (2022)

Note: Population figures *United States Census Bureau (2026), **Statistics Canada (2021)

Table 3 Europe

City/Country	Population	Learning experience	References
Amsterdam, The Netherlands	1.189 million (Metro Area)*	Using the Land Transformation Model, a geographic information systems (GIS)-based artificial neural network (ANN) land use prediction tool, has helped Amsterdam protect its infrastructure from sea level rise.	Kim & Newman (2019)
Copenhagen, Denmark	1.401 million (Metro Area)**	Copenhagen has become a centre for novel experiments in designing climate-resilient urban spaces through multidisciplinary and site-specific strategies. These require innovative project management involving collaboration of various stakeholders, including citizens. Nature-based solutions to landscape design can address environmental, social and economic challenges presented by climate change.	Negrello (2023)
London, United Kingdom (UK)	10.416 million***	London's city government has a robust capacity for autonomy, which is made possible through stakeholder participation, local leadership and coordination that focuses on climate action and mobility. Despite the UK's departure from the EU in 2020, the national political framework remains supportive.	Drummond (2021)
Madrid, Spain	6.811 million (Metro Area)****	Madrid is aiming to reduce greenhouse gas (GHG) emissions by 65% by 2030 and to become carbon-neutral in 2050, through a policy roadmap that prioritises carbon emissions and sustainable transportation solutions.	Ciambra et al. (2023)
Milan, Italy	3.167 million (Metro Area)*****	A climate-related transition has become relevant to the construction industry. In this context, the city of Milan has designed new buildings and infrastructures in the Milan Innovation District (MIND), which is an Italian development in the city, pioneering the transition to resilient green urban planning.	Boschi (2023)
Paris, France	9.382 million***	Climate change adaptation and mitigation policies in Paris include opportunities for solar radiation management (SRM) through afforestation and geoengineering. It is necessary to evaluate mitigation solutions to reduce global temperatures, while identifying constraints and developing policies to integrate them cooperatively, striving for an effective, long-term, policy approach to climate change.	Santos et al. (2022); Masson et al. (2013)

Table 3 (continued)

City/Country	Population	Learning experience	References
Rome, Italy	4.347 million (Metro Area)******	The urban forestation project, funded by the EU, is the main approach to climate mitigation in Rome, which will see nearly 560,000 trees planted in the city by 2026, especially in the eastern zone, which is the most sensitive to climate change impacts.	Sabelli (2023)
Stockholm, Sweden	1.738 million (Metro Area)*******	Stockholm has developed a comprehensive approach to modelling GHG emissions from urban developments as priority measures to counteract climate change. This strategy has shown that a zoning policy, restricting urban development in certain areas, has the potential to mitigate 72% of the total emission effects of the projected urban sprawl.	Pan et al. (2020)

Note: Population figures *Macrotrends (2025c), **Macrotrends (2025d), ***UN DESA (2025), ****Macrotrends (2025e), *****Macrotrends (2025f), ******Macrotrends (2025g), *******Macrotrends (2025h)

Table 4 Asia

City/Country	Population	Learning experience	References
Beijing, China	17.013 million*	Implementation of an ecosystem-based approach, The Sponge City Development initiative, to address the water-related challenges of urbanisation and climate change in Beijing as an integrated part of its urban development, increase resilience to climate change, and improve urban sustainability.	Ma & Jiang (2023); Zhang et al. (2018)
Fukuoka, Japan	5.466 million (Metro Area)**	Application of climate change adaptation policies, particularly in urban and green space planning. Fukuoka, which was an early adopter of municipal climate action, has demonstrated adaptation responses for an expanding Asian city, as a result of its long tradition of science-policy linkages.	Mabon et al. (2019)
Seoul, Republic of Korea	22.490 million*	Implementation of the "One Less Nuclear Power Plant" (OLNPP) policy in Seoul supports the city's transition to a more resilient energy regime. The policy was launched with a target of cutting energy use by 2 million tons of oil, which is equivalent to the amount of electricity generated annually by an average nuclear power plant in Korea.	Cho (2020)
Surat, India	6.909 million*	Climate change adaptation policies are integrated into urban planning in Surat, showing the trade-offs associated with how different urban actors plan and implement adaptation practices in the context of rapid industrialisation. The city's engagement with the Asian Cities Climate Change Resilience Network is highlighted.	Chu (2016)
Tokyo, Japan	33.413 million*	As part of the Society 5.0 initiative, an information-sharing platform is used to share climate change and disaster information among stakeholders, including academia. In addition, the Tokyo Metropolitan Government's adaptation policies contribute to climate change adaptation.	Mavrodieva & Shaw (2020); Hijioka et al. (2016)

Note: Population figures *UN DESA (2025), **Macrotrends (2025i)

Table 5 Latin America

City/Country	Population	Learning experience	References
Bogotá, Colombia	10.624 million*	In 1998, a transformation began in Bogotá's transport system. So far, more than 300 km of bike paths have been built, stretching from slum areas and suburbs to the centre of the capital. The route includes a leisure network, local bike lanes, and a long system of green areas. Public transport has also been improved. TransMilenio is a fast, accessible and comprehensive bus system.	Gonzalez et al (2020)
Curitiba, Brazil	3.889 million (Metro Area)**	The city has implemented a climate plan (PlanClima), which includes measures such as establishing zero emission or low emission zones, promoting green public procurement, subsidy schemes to encourage the adoption of clean vehicle technology, and digitalisation of the transport system. This involves an integration of smarter public transport services and digital platforms that connect bike sharing, taxis and public transport for enhanced efficiency and sustainability.	Leite de Almeida et al. (2021)
Mexico City, Mexico	17.734 million*	Mexico City has implemented a planning tool known as the Climate Action Programme (PACCM), consisting of 5 strategic areas and 69 distinct actions. The aim is to mitigate environmental, social and economic risks associated with climate change while promoting citizens' wellbeing. To facilitate ongoing PACCM monitoring, a dedicated computer tool, the Virtual Centre for Climate Change in Mexico City (CVCCCM), has been developed.	SedeMA (2016)
San José, Costa Rica	1.503 million (Metro Area)***	The city of San José's policies and actions must align with the national objectives of the National Decarbonisation Plan. This plan assists the country in reaching net-zero emissions by 2050, through the decarbonisation of the transport and energy sectors.	Godínez-Zamora et al. (2020)
Santiago, Chile	6.726 million*	The municipal government of Santiago, in collaboration with the federal government, has developed a plan for new urban parks. The new parks are designed to improve quality of life for families and communities with a higher degree of social vulnerability.	Programa Cidades Sustentáveis (2024)

Note: Population figures *UN DESA (2025), **Macrotrends (2025j), ***Macrotrends (2025k)

Table 6 Australia and Oceania

City/Country	Population	Learning experience	References
Auckland, New Zealand	1.711 million (Metro Area)*	Auckland Council is currently implementing the city's Climate Plan, which focuses on equity and has clear greenhouse gas (GHG) reduction targets for the Auckland region, including halving emissions by 2030 and reaching net zero emissions by 2050, including through decarbonising urban mobility. This adaptive transition plan underscores the importance of institutional and community learning for developing and leveraging the knowledge, capacities and behaviours needed to support low-carbon urban futures.	Auckland Council (2020); Jalali et al. (2024); OECD (2020)
Brisbane, Australia	2.568 million (Metro Area)**	Brisbane's urban development has exacerbated climate change and increased the city's vulnerability to resultant impacts. Remote sensing research estimates that urban development has resulted in losses of approximately USD 4.5 billion in ecosystem services. Following catastrophic flooding in 2011, and preparing to host the 2032 Olympic Games, climate learning in Brisbane is demonstrated via measures that increase its climate resilience against droughts, bushfires, storms and flooding, thereby strengthening urban management policies.	Kozlowski & Yusof (2016); Mortoja & Yigitcanlar (2020)

Table 6 (continued)

City/Country	Population	Learning experience	References
Melbourne, Australia	5.392 million*** (Melbourne Metro Area)	Royal Botanic Gardens Victoria (RBGV) is implementing a "Landscape Succession Strategy" that considers the future impacts of climate change. Its climate change-conscious approach recognises that trees planted today must suit a twenty-second-century climate. Learning in the City of Melbourne is exemplified by the RBGV strategy to "transition" the majority of its plant species to make them resilient to the climate modelled for 2090.	Entwisle et al. (2017); RBGV (2016)
Perth, Australia	2.169 million (Metro Area)****	Climate change-related learning in Perth has resulted from institutional education programmes and staff capacity building. Engaging 70 co-called Sustainability Champions ("change agents") as catalysts for "culture change", the key learning of this longitudinal case study is that change may be championed not only from the top down by a mayor or politicians, but also from the bottom up by officers within the administration, which the study calls "boundary spanners and change agents – the humans in the system" (Bryant & Thomson 2021, p. 806).	Bryant & Thomson (2021); Scott & Moloney (2022)

Table 6 (continued)

City/Country	Population	Learning experience	References
Sydney, Australia	5.249 million***** (Sydney Metro Area)	Sydney's urban heat island (UHI) effect contributes to heatwave-related human mortality. Research shows that future heatwave days may increase fourfold but that heat thresholds would not be breached without the UHI effect. The City of Sydney's learning is demonstrated via strategies that upscale tree planting and increase tree canopy cover, thereby reducing urban heat.	Chaston et al. (2022); Greater Sydney Landcare (2024); City of Sydney (2023).

Note: Population figures *Macrotrends (2025l), **Macrotrends (2025m), ***Macrotrends (2025n), ****Macrotrends (2025o), *****Macrotrends (2025p)

Results and discussion

Our case study analyses raised key themes that reflect the learning of the selected cities in mitigating climate change and adapting to its effects. Strategies include nature-based solutions, multi-stakeholder collaboration, community engagement and education, innovation in areas of policy and governance, technological solutions, addressing issues of equity and social inclusion, and tactics associated with long-term planning and adaptation.

Nature-based solutions

Rome and Sydney have embraced nature-based solutions to mitigate climate change impacts and enhance resilience (Chaston et al. 2022). These metropolitan agglomerations are their respective countries' largest cities and are similarly characterised by grey infrastructure and impervious development that affect microclimates in high-density environments (Edmondson et al. 2016). In Rome, "heatwaves are already longer and more frequent than a few decades ago" (Sabelli 2023, para 2), and "Sydney could experience a fourfold increase in numbers of heatwave days and heatwave-attributable deaths by 2100" (Chaston et al. 2022, p. 11). The urban heat island (UHI) effect exacerbates heatwave-related human health problems and mortality (Edmondson et al. 2016). Both cities have embraced widespread tree-planting strategies, recognising that "increasing tree cover will mitigate the impact of urban heating" (Chaston et al. 2022, p. 10). The cooling impact of trees in urban environments is well established (Rahman et al. 2020), and modelling has shown that increased tree cover can lead to "marked decreases" in heatwaves (Chaston et al. 2022, p. 7). In Rome, the urban forestation project aimed to plant 560,000 trees by 2026 (Sabelli 2023). Similarly, Sydney has adopted strategies that seek to expand tree canopy cover to reduce urban heat (Chaston et al. 2022; Greater Sydney Landcare 2024; City of Sydney 2023). Universities can assist through tree planting (Leal Filho et al. 2024) or aid campus-greening efforts by implementing community gardening, as illustrated by the example of Brisbane (Luetz and Beaumont 2019). Nature-based solutions can also mitigate other types of climate-change impacts, including flood damage, as highlighted in comparative analyses between Amsterdam and Houston (Kim and Newman 2019). Nature-based solutions have been proposed as mainstream adaptation measures for a wide range of cities, including Cairo, Barcelona, Malmö and Utrecht (Cortinovis et al. 2022; Dabaieh et al. 2024).

Multi-stakeholder collaboration

Collaboration among stakeholders, including government agencies, academia, businesses and civil society, emerges as a common perspective in the learning approach to support climate action and has been applied successfully in several cities, including Madrid, Houston, Curitiba, Surat and Copenhagen. By fostering partnerships and interdisciplinary approaches, cities can develop comprehensive climate action plans and their effective implementation (Haupt 2021). In Copenhagen, the involvement of diverse stakeholders, including private actors, has created conditions for planning new climate-resilient urban spaces with multidisciplinary approaches, considering local characteristics (Negrello 2023). Madrid's plans to reduce its greenhouse gas emissions and become carbon-neutral by 2050 exemplify stakeholder involvement in the climate action planning process (Ciambra et al. 2023). Their engagement in the implementation phases is also crucial to the success of resilience projects, as Curitiba showed in its climate plan (PlanClima), guiding policies and actions to adapt to climate change, with the contribution of local and international organisations (Leite de Almeida et al. 2021).

Stakeholder involvement in the climate action process also occurs through information and indicator sharing, as seen in Tokyo; via the use of digital platforms (Mavrodieva and Shaw 2020; Hijioka et al. 2016) by raising awareness among the actors involved, as in the case of Lagos; and/or with periodic stakeholder awareness programmes (Elias and Omojola 2015), as suggested by Taedong Lee and Susan van de Meene (2012). In this scenario, the involvement of cities in professional and learning networks plays a significant role in sharing best practices and lessons learned among stakeholders, while increasing the engagement of private actors and the general public, as seen in Surat (Chu 2016).

Community engagement and education

Cities such as Lagos, Nairobi, Dammam, Perth and Abu Dhabi have recognised the importance of engaging their communities through awareness programmes, capacity-building initiatives and educational campaigns. By involving citizens – especially children, community and government leaders – in climate literacy efforts, cities can foster a culture of sustainability and encourage individuals to take proactive measures.

By way of illustration, the Paperless Day initiative in Abu Dhabi was intended to create awareness and encourage individuals and organisations to reduce paper use, thereby contributing to water and energy conservation (Menhali and Ahmed 2014). In Perth, local government staff were engaged for five years in a culture change programme focused on sustainability (Bryant and Thomson 2021; Scott and Moloney 2022). Nairobi showed how community engagement can play a crucial role in promoting sustainable behaviours and lifestyles. Residents from nine Kenyan villages showcased the effectiveness of raising awareness and enhancing the community's ability to absorb, adapt and transform in response to climate challenges (Muchiri et al. 2022). Postgraduate students in Dammam engaged in a social project to strengthen their country's economy in line with Saudi Arabia's national development plan, Vision 2030 (Alghamdi Hamdan and Aldossari 2021). Similarly, climate change education in Lagos has focused on school children, programmes for government staff, and summits to educate stakeholders and the community (Elias and Omojola 2015).

These case studies exemplify how learning can serve as a critical catalyst to drive transformative changes towards sustainability and climate action.

Policy and governance innovation

Policy innovation and effective governance structures play significant roles in cities such as Paris, London or Tokyo. For example, a study by Yasuaki Hijioka et al. (2016) suggested that current policy provisions for Tokyo could help this city adapt to climate change, because these are based on a thorough inspection of specific sectors and indicators, making these guidelines applicable to many sectors of the Japanese economy and urban management. A new, all-inclusive plan known as "Society 5.0" has been launched in Japan in collaboration between the government and private companies to employ ground-breaking sustainability solutions (Mavrodieva and Shaw 2020).

By contrast, policy endeavours for climate change adaptation in Paris and many other European cities prioritise opportunities for solar radiation management (SRM) through afforestation to mitigate the "heat island" effect (Masson et al. 2013). Geoengineering technologies are envisioned, too, despite possible hazardous side effects. It is essential to carefully evaluate solutions for urban environments, identifying constraints, developing guidelines, and striving to integrate these for an effective, long-term approach to climate change adaptation and mitigation (Santos et al. 2022). To diminish greenhouse gas emissions while integrating climate considerations into urban planning processes, London has focused on mobility and, despite the UK's withdrawal from the EU, the national political agenda remains supportive. However, Paul Drummond (2021) concedes that spatial variation in urban form and infrastructure, matched by dual-layer city administration, often confounds social and political environments and commitments to climate action.

Technological solutions and innovation

In response to the challenges posed by industrialisation, urbanisation and climate change, cities worldwide are turning to innovative technological approaches to enhance climate action and sustainability. For example, Beijing has implemented the Sponge City Development initiative, utilising innovative construction techniques and green infrastructure to manage water resources (Ma and Jiang 2023; Zhang et al. 2018). Vancouver adopted sophisticated monitoring systems and data-driven models to track environmental parameters, identify vulnerabilities and formulate targeted adaptation strategies (Simonovic and Peck 2022). These technological solutions enable policymakers to make informed decisions based on real-time data and predictive analytics, thereby enhancing the city's overall resilience (Fu et al. 2025; Leal Filho et al. 2023). Melbourne's Royal Botanic Gardens Victoria has applied its Landscape Succession Strategy to adapt plant species for future climate conditions (Entwisle et al. 2017; RBGV 2016; Lauer et al. 2023). In Mexico City, the Climate Action Programme (PACCM) addresses climate risks and promotes social and economic wellbeing, supported by a monitoring tool (SedeMA 2016). Milan's Milan Innovation District (MIND) pioneers resilient urban planning, integrating innovative designs to enhance urban liveability and mitigate climate risks (Boschi 2023).

Moreover, remote sensing technologies play a pivotal role in monitoring environmental changes and assessing climate-related risks in cities such as Milan, Mexico City and Melbourne. These cities use satellite imagery and other remote sensing tools to gather spatial data, monitor land use changes, and assess the effectiveness of adaptation measures. By integrating remote sensing data into decision-making processes, urban planners can better understand the dynamics of urban environments and implement context-specific interventions to enhance resilience (Iqbal et al. 2025). These cities demonstrate the transformative potential of technological innovation in enhancing cities' resilience, while informing climate adaptation strategies. Collectively, the experiences of these cities illustrate the transformative potential of technological innovation in building resilient urban environments.

Equity and social inclusion

Equity and social inclusion emerge as critical considerations in cities such as Bogotá, San José, Santiago and Auckland. Climate action plans prioritise vulnerable communities, promote social equity and address environmental justice concerns (Fiack et al. 2021). By ensuring that adaptation measures are inclusive and equitable, cities can build resilience while minimising climate impacts across all districts. Bogotá is recognised for its proactive urban development policies and programmes that aim at achieving equity and social inclusion. The city's embrace of the idea of an intelligent city and sustainable transportation envisions developing an inexpensive and available public transportation system (Gonzalez et al. 2020). By promoting green space development and intelligent transportation systems, Bogotá is hoping to improve social equity and ensure that its infrastructure benefits every resident. Similarly, in San José, efforts to decarbonise transport and energy systems are both central to the city's climate change response and part of a broader push for greater social equality and cohesion (OECD 2020).

According to Guido Godínez-Zamora et al. (2020), emission reduction policies can help to mitigate environmental injustice in impoverished communities, granting residents a stake in green energy and clean transportation. For example, the creation of green spaces and parks in Santiago supported social integration while enhancing residents' leisure possibilities and life quality. Such projects demonstrate a city's resolve to tackle the problem of social inequity and guarantee that everybody has access to public amenities and services (Programa Cidades Sustentáveis 2024). In Auckland, the focus on the relationship between urban microclimate and residential energy demands is an example of the city's ambition to improve the quality of life for everyone. It is addressing energy poverty by ensuring access to affordable and sustainable energy services for at-risk individuals, thus promoting emancipation from poverty and environmental justice (Jalali et al. 2024).

On the topic of equity and social inclusion, Bogotá, San José, Santiago and Auckland have embraced lifelong learning and climate education as tools for empowering those communities most vulnerable to climate change. In Bogotá, community-based environmental education initiatives and urban agriculture programmes foster inclusive learning experiences and shared responsibility for green space management (Metropolis 2020;

UIL 2024). In San José, learning is reflected through strategies aimed at decarbonising urban transport and promoting sustainable mobility. Universities and research institutions play a key role in advancing this learning process by contributing to scenario modelling, stakeholder engagement, and the co-design of low-carbon urban policies (Godínez-Zamora et al. 2020). Also in San José, experiential learning programmes and adult education opportunities promote environmental stewardship and civic engagement, particularly among youth and underserved groups (UNESCO 2020). In Santiago, national policies support environmental education from early schooling through adolescence, with strong community-based components (UNESCO 2022, 2023). Auckland integrates equity into its strategic vision through the Auckland Plan 2050, which prioritises lifelong learning and sustainability education to support inclusive urban resilience (Auckland Council 2018; NZC 2023; Everth et al. 2021). These cities demonstrate policies that ensure equality and social inclusion in urban design.

Long-term planning and adaptation strategies

Finally, many cities have adopted long-term planning and adaptation strategies to proactively address climate change. These cities include Tehran, Surat, Accra, Brisbane and Fukuoka. By anticipating future climate risks, cities can invest in climate-resilient infrastructure and promote disaster preparedness, thus reducing vulnerability and increasing adaptive capacity (Ghasemzadeh and Sharifi 2020; Kozlowski and Yusof 2016). To this end, cities leverage both relevant networks and historical opportunities. Examples include Surat's engagement with the Asian Cities Climate Change Resilience Network (ACCCRN), which is tasked with supporting climate change resilience among poor and vulnerable urban communities in Asia, and Brisbane's preparations to host the Olympic and Paralympic Games in 2032, which offers the city a chance to become the first host city in the world "to be contractually obliged to be 'Climate Positive' " (Heynen and Vanaraja Ambeth 2023, p. 1) and thus "goes further to absorb or remove more [emissions] than it produces to become 'carbon negative' – a synonym for climate positive" (Climate Council 2021, para 5). Long-term planning and adaptation strategies are manifold and involve a range of approaches, including identifying and overcoming "planning barriers", as in the case of Tehran (Ghasemzadeh and Sharifi 2020); making "targeted investments" to mitigate flood risk, as in the cases of Accra and Brisbane (Cobbinah and Poku-Boansi 2018; Kozlowski and Yusof 2016; Mortoja and Yigitcanlar 2020); implementing policies involving "greenspace planning", as in the case of Fukuoka (Mabon et al. 2019); and adopting planning processes conjoining "public and civic actors", as in Surat (Chu 2016).

Conclusion

Our thematic case-study analyses reveal key emergent themes and learning experiences in mitigating and adapting to climate change in cities. These themes encompass nature-based solutions, multi-stakeholder collaboration, community engagement and education, innovation in policy and governance, technological solutions, equity and social inclusion, and long-term planning and adaptation. These case studies offer useful lessons that may inform ongoing climate change adaptation efforts in other cities. For instance, Rome and Sydney are implementing extensive tree-planting initiatives to mitigate UHI effects and build resilience against heatwaves (Chaston et al. 2022; Edmondson et al. 2016).

Copenhagen and Madrid use multi-stakeholder collaboration, facilitating comprehensive climate action plans through inclusive and interdisciplinary approaches (Negrello 2023; Ciambra et al. 2023). Abu Dhabi and Perth exemplify effective community engagement efforts by raising awareness, educating the public and mainstreaming sustainable practices (Menhali and Ahmed 2014; Bryant and Thomson 2021). Tokyo and London exemplify adaptive policy frameworks and urban planning in addressing climate challenges (Hijioka et al. 2016; Drummond 2021). Beijing's Sponge City initiative and Vancouver's data-driven environmental monitoring systems showcase technological solutions and innovation that enhance climate adaptation and urban resilience (Ma and Jiang 2023; Simonovic and Peck 2022). In Bogotá and San José, strategies emphasise equity and social inclusion, thereby illustrating how climate action plans prioritise vulnerable communities and promote social justice (Fiack et al. 2021; Godínez-Zamora et al. 2020). Finally, Tehran and Brisbane offer lessons on the benefits of long-term planning and adaptation strategies, including making proactive financial investments in climate-resilient infrastructure and disaster preparedness (Ghasemzadeh and Sharifi 2020; Heynen and Vanaraja Ambeth 2023).

To fully foster lifelong learning on climate change, individuals should engage in continuous self-education through online courses and by gaining certifications from institutions such as the UN Climate Change Learning Partnership.[3] Community-based learning – such as local climate action workshops or citizen science projects – can create bridges between theory and practice. Professionals should pursue industry-specific upskilling, such as green building design or carbon accounting, through massive open online course (MOOC) provider platforms such as edX. Governments and non-governmental organisations (NGOs) must promote accessible, localised content (podcasts, documentaries, and mobile apps) to reach diverse audiences. Finally, intergenerational knowledge-sharing – through schools, mentorship or public forums – ensures that climate literacy evolves with science and empowers collective action. In sum, the learning experiences of the 34 cities included in this study offer helpful insights into strategies that municipalities can employ to address the complex challenges of climate change.

Finally, it is worth noting that this article has a few limitations. The first is the size of our sample. Furthermore, our study was limited to a single set of parameters and did not gather first-hand original data, such as through interviews. But despite these constraints, this article offers useful insights into current strategies being employed in a wide range of locations to deliver climate action, which is urgently needed, within a lifelong learning framework.

[3] For more information, visit https://uncclearn.org/ [accessed 24 June 2026].

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Walter Leal Filho is a distinguished "Euro-Professor", holding professorial posts at Universities in Germany (Chair of Climate Change Management at the Hamburg University of Applied Sciences), the United Kingdom (Manchester Metropolitan University), Sweden (University of Uppsala) and Poland (Merito University).

Yusuf A. Aina lectures at the Department of Geomatics Engineering Technology at Yanbu Industrial College, Saudi Arabia. He has published articles in academic peer-reviewed journals, as well as book chapters and conference proceedings. His research interests include urban geographic information system (GIS)/remote sensing applications, human-induced environmental change, environmental impact assessment (EIA)/strategic environmental assessment (SEA), smart cities, urban sustainability, and GeoAI.

Luciana Londero Brandli, PhD, is a professor at the University of Passo Fundo, Brazil, and a researcher in the Graduate Programme in Civil and Environmental Engineering. She completed her postdoctoral studies in Applied Sciences at Hamburg University of Applied Sciences in Germany. Her areas of expertise include Sustainability, Higher Education, Sustainable Development and Environmental Management. Professor Brandli has extensive international experience, having collaborated with institutions around the world. She serves on the editorial boards of various journals, supervises several master's and doctoral students in engineering, environmental, and sustainability issues, and has authored over 300 publications, including books, book chapters and peer-reviewed journal articles.

Johannes M. Luetz, PhD, is Professor of Sustainability and Religion, Director of Graduate Research and Research Development, and Human Research Ethics Chair at Alphacrucis University College, based in Brisbane, Australia. He is an interdisciplinary social scientist whose work examines ecological and climate adaptation challenges through spiritual, humanitarian and policy lenses, with a particular focus on worldview-inclusive learning. Raised across Sierra Leone, Switzerland, Germany and Australia, he has conducted research at the science–faith, interfaith, and science–policy interfaces. He is Adjunct Associate Professor at the University of New South Wales and Adjunct Professor at the University of the Sunshine Coast, and serves on the editorial boards of international journals.

Roberto Schoproni Bichueti is a Professor in the Department of Administrative Sciences at the Federal University of Santa Maria (UFSM) in Brazil as a Permanent Professor of the Postgraduate Programme in Administration and Accounting Sciences (PPGACC-UFSM). He completed his bachelor's degree (2010), master's degree (2013) and PhD (2016) in Business Administration at UFSM. He carried out postdoctoral research (2024) at the Hamburg University of Applied Sciences (HAW) in Germany, as an International Visiting Professor. He develops studies on Strategy, Sustainability, Innovation and Climate Change, focusing on Sustainable and Smart Cities; Urban Resilience; and Innovation and Entrepreneurship Environments.

Bruno Borsari, PhD, is Emeritus Professor in the Department of Biology at Winona State University, in Winona, Minnesota, USA. An agroecologist by trade, his research agenda includes urban ecology, permaculture and landscape architecture. To his credit Dr Borsari has more than 150 publications. He is currently collaborating with the Universidad Regional Amazonica (IKIAM) in Ecuador.

Ricardo Luiz Fernandes Bella is a postdoctoral researcher in entrepreneurship, sustainability and digitalisation at the Hamburg University of Applied Sciences (HAW) in Germany, supported by an Overseas Postdoctoral Fellowship (PDE) from the National Council for Scientific and Technological Development (CNPq) in 2024. Has experience in Economic and Organisational Engineering, Project and People Management, Risk Management, and Multicriteria Evaluation Methods. He has held the position of a full-time Assistant Professor in the Department of Engineering at the Fluminense Federal University (UFF) in Rio de Janeiro, Brazil, since 2018.

Abdulaziz I. Almulhim is an internationally recognised scholar in urban sustainability, urban resilience and climate change. He is an Associate Professor of Urban Sustainability at Imam Abdulrahman Bin Faisal University, Saudi Arabia. His research critically examines urban planning under conditions of rapid urbanisation, climate stress and environmental constraint. He has published over 70 peer-reviewed articles and is recognised among the world's top 2% of scientists (Stanford University). He serves as Lead Author for the IPCC Special Report on Climate Change and Cities (2027) and serves on editorial boards of leading international journals. His work advances resilient, sustainable, climate-positive urban futures globally.

Edward Mendy is a PhD Scholar in Climate Change and Disaster Risk Management at the Université de Lomé in Togo under the prestigious scholarship programme of the West African Science Service Center on Climate Change & Adapted Land Use (WASCAL). He is currently on a scientific research visit at the Hamburg University of Applied Sciences (HAW) in Germany, under the supervision of Prof Dr Walter Leal in the Research and Transfer Center "Sustainability and Climate Change Management". His research topic is "Assessment of flood risks and Indigenous knowledge employed in flood management along the Gambia River".

Authors and Affiliations

Walter Leal Filho[1,2] · Yusuf A. Aina[3] · Luciana Brandli[4] · Johannes M. Luetz[5,6,7] · Roberto Schoproni Bichueti[8] · Bruno Borsari[9] · Ricardo Luiz Fernandes Bella[10] · Abdulaziz I. Almulhim[11] · Edward Mendy[12]

✉ Yusuf A. Aina
yaina@rcjy.edu.sa

Walter Leal Filho
walter.leal2@haw-hamburg.de

Luciana Brandli
brandli@upf.br

Johannes M. Luetz
jluetz@usc.edu.au

Roberto Schoproni Bichueti
roberto.bichueti@ufsm.br

Bruno Borsari
bborsari@winona.edu

Ricardo Luiz Fernandes Bella
ricardobella@id.uff.br

Abdulaziz I. Almulhim
aialmulhim@iau.edu.sa

Edward Mendy
mendy.e@edu.wascal.org

1 Department of Natural Sciences, Manchester Metropolitan University, Manchester, UK

2 Hamburg University of Applied Sciences (Hochschule fur Angewandte Wissenschaften Hamburg), Hamburg, Germany

3 Department of Geomatics Engineering Technology, Yanbu Industrial College, Yanbu, Saudi Arabia

4 Civil and Environment Engineering, University of Passo Fundo (Universidade de Passo Fundo),

Passo Fundo, Brazil

[5] Graduate Research School, Alphacrucis University College (AC), Brisbane, Australia

[6] School of Law and Society, University of the Sunshine Coast (UniSC), Maroochydore, Australia

[7] School of Social Sciences, University of New South Wales (UNSW), Sydney, Australia

[8] Department of Administrative Sciences, Federal University of Santa Maria (Universidade Federal de Santa Maria), Santa Maria, RS, Brazil

[9] Department of Biology, Winona State University, Winona, MN, USA

[10] Department of Engineering, Fluminense Federal University (Universidade Federal Fluminense), Rio das Ostras, Brazil

[11] Department of Urban and Regional Planning, College of Architecture and Planning, Imam Abdulrahman Bin Faisal University, 31451 Dammam, Saudi Arabia

[12] Climate Change and Disaster Risk Management, University of Lome: (Universite de Lome), Lome, Togo