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Indigenous climate change mitigation strategies in tropical cities – a review

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Introduction: Climate change poses numerous issues for indigenous populations in tropical cities worldwide, including reduced access to food, dwindling resources, and the proliferation of vector-borne illnesses. Indigenous communities are developing various mitigation and adaptation measures suitable for their distinct cultural and ecological demands.

Methods: This study investigates the numerous indigenous climate change mitigation strategies (ICCMSs) being deployed in tropical cities, using secondary sources of data. The methodology involved a systematic review based on PRISMA guidelines, encompassing the identification, screening, eligibility, and inclusion of relevant literature. From an initial 1,200 sources, 450 were screened, and 102 met the inclusion criteria for full-text assessment.

Results: Findings indicate that common ICCMSs in tropical cities include the use of traditional knowledge systems and materials in urban green infrastructure projects, agroforestry, sustainable urban agriculture, urban afforestation and reforestation, and indigenous technologies and innovations in waste management practices. Indigenous peoples have benefited from greater education and understanding about climate change, empowering them to take action and lower their greenhouse gas (GHG) emissions.

Discussion: The study recommends that governments and international organizations support these mitigation efforts, incorporate them into public policy and urban planning for indigenous communities in tropical cities, and reduce global anthropogenic GHG emissions. Further studies are suggested to assess the effectiveness of these measures and their potential to enhance climate resilience in tropical cities.

KEYWORDS
indigenous climate change mitigation strategies, tropical cities, urban planning, policy frameworks, traditional knowledge

1 Introduction

Vulnerable groups, especially indigenous communities in tropical cities, are disproportionately affected by climate change (Higgins, 2022; Nursey-Bray et al., 2022; Daiyan, 2023; Ramazanu et al., 2023). High population density, rapid urbanization, and an amalgam of traditional and modern infrastructure characterize tropical cities (Giridharan, 2016; Li et al., 2021; Oloke et al., 2021). According to Li et al. (2021) and Ogunbode (2021), these urban environments often face unique issues associated with climate change such as extreme heat islands, flooding brought on by inadequate drainage systems, and increased pollution levels. Furthermore, tropical cities are important areas for investigating climate change mitigation strategies because they typically have rich biodiversity and are located in regions considered extremely vulnerable to the impacts of the climate. Oloke et al. (2021) observe that tropical cities in developing countries like Nigeria often do not have the necessary planning, infrastructure, and resources to successfully manage the impacts of climate change. Nigeria is highlighted due to its sizeable indigenous population facing diverse climate-related challenges representative of broader issues in Africa and globally (Ogunbode, 2021; Tanimonure, 2021).

The term "urban indigeneity" describes the distinctive ways that indigenous peoples coexist and engage with urban settings while keeping their cultural identities and practices. In order to build resilient, sustainable, and culturally inclusive cities, indigenous urbanism integrates indigenous knowledge and practices into urban planning and development (see DeGruyter, 2023; Wiley, 2023). While the vast majority of the research already in the literature focused on the Global North, this study tries to close the gap by examining these notions in the context of tropical cities in the Global South.

Indigenous peoples in Nigeria, with strong ties to their environments, rely on traditional knowledge for cultural identity and sustenance. However, climate change threatens traditional livelihoods such as pastoralism, fishing, and agriculture. Rising temperatures, erratic rainfall, and prolonged droughts reduce productivity, increase food insecurity, and cause displacement, worsening poverty (Ebele and Emodi, 2016; Ogunbode, 2021; Tanimonure, 2021; Osuji et al., 2023). Severe weather events like heat waves, storms, and floods heighten risks, causing property damage, fatalities, and economic instability. Inadequate infrastructure compounds existing disparities and marginalization, while vector-borne diseases strain overburdened healthcare systems with limited access (Ebele and Emodi, 2016). Addressing these issues requires inclusive, equitable, and culturally sensitive methods.

Indigenous knowledge, built on years of experience, offers insightful solutions. Indigenous climate change mitigation strategies (ICCMSs) are critical for their efficacy, cultural relevance, and ability to build resilience in vulnerable populations (Tolo et al., 2014; Bethel et al., 2021; Jerez, 2021). These strategies leverage traditional knowledge systems that provide perspectives on risk reduction, adaptability, and sustainable resource management (Mugambiwa, 2018; Jerez, 2021). Indigenous approaches often have close ties to local ecosystems, using biodiversity and natural processes to mitigate climate change impacts (Bethel et al., 2021). Practices like agroforestry, traditional farming, and community-based conservation reduce greenhouse gas emissions while enhancing ecosystem services and biodiversity (Tolo et al., 2014). ICCMSs also promote social resilience and adaptive capacity, being firmly anchored in cultural values and community solidarity (Bethel et al., 2021; Jerez, 2021). These strategies enhance self-reliance, cultural continuity, and equitable development by empowering indigenous people to preserve and revive traditional practices (Imoro et al., 2021). Recognizing and integrating indigenous knowledge into climate change mitigation efforts is vital for advancing social justice, sustainability, and resilience.

This review article investigates ICCMSs in tropical cities, focusing on their effectiveness, relevance, and potential integration into urban planning and policy frameworks.

2 Methodology

This study utilized a systematic review approach based on the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) guidelines, which have been used in other studies (Abubakar et al., 2022; Balogun et al., 2022; Gazzeh et al., 2022) to collect and analyze data from existing literature. As depicted in Figure 1, the research process is divided into four phases: identification, screening, eligibility, and inclusion.

2.1 Identification

Defining the research problem, boundaries, and limits of the study were all part of the scoping phase. The primary objective of this paper was to investigate ICCMSs, focusing on how well they operate, how applicable they are, and how they may be included into tropical city policy frameworks and urban planning. The identification of pertinent keywords – Indigenous climate change mitigation strategies, tropical cities, urban planning, policy frameworks, and traditional knowledge – made the literature search easier. These keywords were selected in accordance with the research question and objective to guarantee a thorough literature search.

2.2 Screening

The second step involved finding and collating pertinent literature from a variety of online sources. The primary databases used for this study were Web of Science, Scopus, PubMed, and Google Scholar. The researchers looked for books, journal articles, conference proceedings, and other peer-reviewed scholarly materials. A total of 1,202 sources were initially identified. The sources were distributed geographically over several continents, with a primary emphasis on Africa, Asia, and Latin America. A substantial volume of literature originated from African countries like Nigeria and Kenya as a result of on-going studies and curiosity about the effects of climate change in these areas. Because of their large populations, rapid urbanization, and rich biodiversity, the southern and southeast regions of Asia are well-represented. Studies are regularly conducted in countries including the Philippines, Indonesia, and India. It is fitting that countries like Brazil and Peru have a significant contribution as the Amazon Basin in Latin America is an important region for climate studies. However, a number of factors, such as the availability of research funding and infrastructure, interest from academics and policymakers, accessibility to data and research publications, and the depth of indigenous and cultural knowledge, can be attributed for the differences in regional representation in the literature.

The collected literature underwent a preliminary screening based on predefined inclusion criteria: (i) relevance to the study's objective; (ii) publication in English; and (iii) publication within the last 20 years. Studies that did not specifically address ICCMSs in tropical cities were excluded from the review. Following the screening, 452 sources were selected for further assessment.

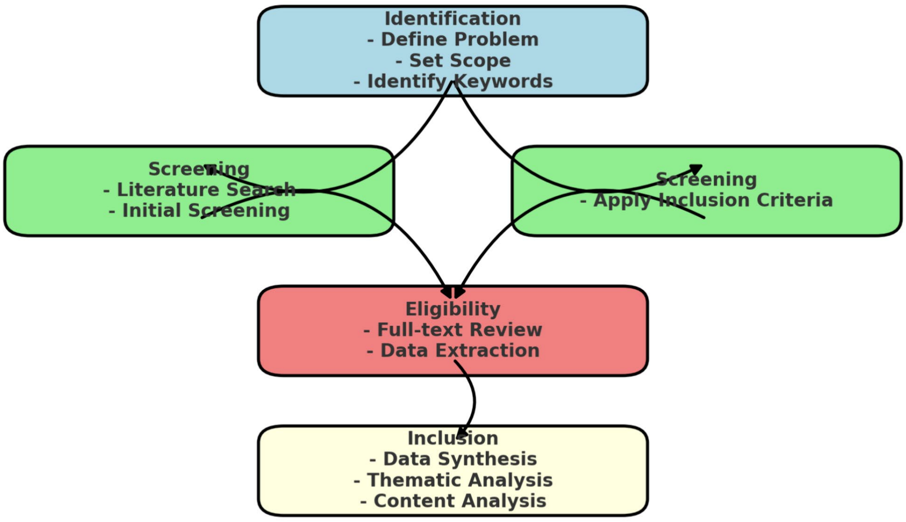

FIGURE 1
PRISMA flowchart of the research methodology.

2.3 Eligibility

The remaining articles were assessed in full text in the eligibility phase to ensure they met the criteria for inclusion. Articles that did not meet these criteria were excluded. From the eligible articles, relevant data were extracted and organized systematically. This included information on the objectives, methods, results, and conclusions of the study on ICCMSs in tropical cities. A total of 302 articles were thoroughly assessed in the full-text assessment, and 104 met the inclusion criteria and were included in the systematic review.

2.4 Inclusion

The data collected were synthesized and analysed in the final phase. The literature was organized into categories according to how related the topics were, with some articles fitting into more than one category. Every document was thoroughly examined to identify, collate, and synthesize themes associated with ICCMSs. To find recurrent themes and patterns, a thematic analysis technique was used, identifying five recurring patterns and themes that emerged from the 104 published works' thematic analysis. Key findings and insights regarding ICCMSs in tropical cities from these were highlighted in this synopsis and discussion of the synthesized data.

3 Indigenous climate change mitigation strategies: conceptual framework

ICCMSs comprise a broad range of methods based in traditional knowledge systems and practices that are adapted to the unique cultural and ecological environments of indigenous people (Ingty, 2017; Bethel et al., 2021; Jerez, 2021). These methods seek to improve community resilience and sustainability while mitigating the impacts of climate change, particularly greenhouse gas emissions. Traditional land management practices that support carbon sequestration and biodiversity conservation include agroforestry and sustainable agriculture (Tolo et al., 2014; Vogel et al., 2022). In order to combat climate change, indigenous people can also make use of renewable energy sources, conventional building materials and techniques, and neighbourhood-based conservation projects (Stewart et al., 2019). Particularly, ICCMSs give community involvement, cultural values, and local knowledge top priority. They provide comprehensive and culturally relevant answers to the many problems that climate change presents for indigenous areas (Stewart et al., 2019; Bethel et al., 2021).

The acknowledgment of the inherent connections between indigenous peoples, their traditional knowledge systems, and their local ecosystems forms the foundation of the conceptual framework used to analyze ICCMSs (Makondo and Thomas, 2018; Bayrak et al., 2020; Bethel et al., 2021; Menon et al., 2023). This framework emphasizes the significance of incorporating indigenous views into climate change mitigation efforts, respecting their distinctive insights, practices, and goals. Fundamentally, this conceptual framework highlights the following important components:

a *Indigenous Knowledge Systems*: are rich and diverse, having developed over many generations as a result of direct interaction with their local settings (Bruchac, 2020; Skroblin et al., 2020; Warbrick et al., 2023). A broad understanding of weather patterns, ecological processes, and resource management strategies are all included in these knowledge systems (Hosen et al., 2020; Skroblin et al., 2020; Salim et al., 2023). Strategies for mitigating climate change could benefit from years of knowledge and experience by recognizing and respecting indigenous knowledge.
b *Cultural Relevance and Contextual Specificity*: Cultural values, beliefs, and practices constitute the foundation of ICCMSs (Ingty, 2017; Bethel et al., 2021; Jerez, 2021). According to Browne et al. (2016) and Domínguez et al. (2017), these strategies are suited to the social, ecological, and economic circumstances of indigenous communities and are

context-specific. Mitigation initiatives can become more efficient, sustainable, and socially just by taking into account cultural variety and local settings.

c *Community Participation and Ownership*: Reyes-García et al. (2018) state that ICCMSs place a high priority on community ownership and involvement, including local stakeholders in project implementation and decision-making processes. Measures are more likely to be effective, culturally and socially acceptable when indigenous groups are given the power and responsibility to direct and oversee mitigation initiatives.

d *Ecosystem-based Approaches*: The utilisation of ecosystem-based techniques is prevalent among Indigenous peoples in their efforts to mitigate the effects of climate change. This approach recognises the interdependence of natural systems and human cultures, as noted by Doswald et al. (2014) and Vogel et al. (2022). It places strong emphasis on promoting ecosystem resilience, managing natural resources sustainably, and conserving and restoring biodiversity. Indigenous communities improve their ability to adapt to changing conditions and mitigate the impacts of climate change by preserving ecosystems and the services they provide.

e *Resilience and Adaptation*: ICCMSs are intrinsically related to adaptation initiatives, acknowledging the necessity of enhancing resilience in the face of environmental shifts (Moore and Schindler, 2022). They emphasize fostering community resilience, bolstering traditional livelihoods, and increasing adaptive ability. Indigenous communities can adapt to climate change and be better able to deal with unpredictability while still maintaining their well-being.

4 Results and discussion

4.1 Leveraging traditional knowledge systems and materials in urban green infrastructure

Urban green infrastructure initiatives in tropical cities are greatly influenced by traditional knowledge systems and materials, which provide substantial knowledge and resources that contribute to climate resilience and sustainable development (Finewood et al., 2019; Mulligan et al., 2020). Indigenous wisdom and heritage are the core of these traditional practices, which are becoming more and more recognized for their ability to improve urban ecosystems, conserve biodiversity, and foster community well-being (Cherchyk and Khumarova, 2023; Štrbac et al., 2023). The use of native plant species for urban greening and landscaping is one instance of traditional knowledge systems in urban green infrastructure initiatives (Law et al., 2017). For food, medicinal, and cultural uses, indigenous inhabitants in tropical cities have long relied on native plant species. They choose plants that are well-suited to the soil types and climate of the area. Cities may support pollinator populations, boost biodiversity, and improve ecosystem services by introducing these native plants into urban green areas like parks, gardens, and greenways (Romali et al., 2023).

Moreover, the creation of sustainable urban green infrastructure requires the use of traditional building materials and construction methods (Abouhelal et al., 2023). Buildings, shelters, and infrastructure are often built by indigenous communities in tropical cities using locally sourced materials including adobe, bamboo, and thatch (Sergeevich et al., 2020; Abouhelal et al., 2023; Romali et al., 2023). Compared to conventional building materials like steel and concrete, these materials are renewable, have low embodied energy, and have a negligible environmental impact (Killemsetty and Behare, 2014; Romali et al., 2023). Cities can lower their carbon footprint, preserve cultural heritage, and develop more climate-resilient built environments by adopting traditional building techniques.

There are numerous instances of parks and green areas incorporating indigenous methods to improve sustainability and cultural relevance in tropical cities throughout the world. The Singapore Botanic Gardens, for example, highlights Singapore's biodiversity and heritage by including local plant species and cultural legacy (Lindsay and Middleton, 2018). The Bosque da Ciência (Science Woods), located in Manaus, Brazil, fosters conservation and cross-cultural exchange through its exhibits of traditional knowledge and native plant species (Horta et al., 2018). Furthermore, the Botanical Garden of Medellín, Colombia, promotes environmental education and community engagement by showcasing indigenous plant species and cultural practices (Egerer et al., 2021). Similar to this, tourists can get a taste of Nigeria's rich natural and cultural heritage at the Millennium Park in Abuja, the country's capital, which incorporates indigenous plant species and traditional architecture elements (Dele et al., 2018). Also, to produce a bio-diverse and culturally rich environment, the Lekki Conservation Centre in Lagos combines traditional landscaping techniques with local plant species (Babafemi et al., 2023). Indigenous trees at the site, like the Nigerian almond and African mahogany, offer visitors shade and habitat for wildlife. The examples provided show how parks, greenways, and other green areas can function as platforms for recognizing indigenous knowledge, fostering the preservation of biodiversity, and facilitating cross-cultural interaction.

4.2 Sustainable urban agriculture and agroforestry

In tropical cities, agroforestry and sustainable urban agricultural practices are essential for boosting food security, conserving biodiversity, and climate resilience (Sistla et al., 2016). Agroforestry systems optimize land productivity and provide ecosystem services by combining trees with crops and/or livestock (Oelbermann and Smith, 2011; Wilson and Lovell, 2016; Bogale and Bekele, 2023). Agroforestry schemes often blend indigenous tree species with food crops, like in Nairobi, Kenya. These initiatives offer several advantages, such as increased soil fertility, water retention, and carbon sequestration (Tschora and Cherubini, 2020). Sustainable urban agriculture practices, such as rooftop gardens, vertical farming, and community gardens, contribute to local food production and environmental sustainability (Albou et al., 2024). Innovative techniques like aquaponics and hydroponics are used in urban agriculture projects in cities like Singapore (Oelbermann and Smith, 2011; Sistla et al., 2016). These techniques enhance community resilience and urban biodiversity, in addition to lowering greenhouse gas emissions and food miles (Bogale and Bekele, 2023). However, these practices are typically community-based rather than indigenous.

Indigenous knowledge provides proven strategies based on regional ecosystems and cultural customs, essential for soil conservation and sustainable land management (Magni, 2017; Williams et al., 2020). Traditional methods like mixed cropping, terracing, and contour farming improve soil fertility, prevent erosion, and foster water retention. Indigenous communities use various agroforestry systems in tropical regions to improve soil health, biodiversity, and climate change resilience (Abas et al., 2022). Consider for example the following case studies:

By integrating trees like *Leucaena leucocephala* with food crops, the Yoruba people in Nigeria practice "alley cropping," which greatly increases the nitrogen content and organic matter in the soil, improving agricultural yields. This is especially helpful in tropical cities where misuse and urban sprawl cause soil degradation (Ahamefule et al., 2020). By reducing their reliance on chemical fertilizers and boosting food security, this increase in crop yields helps smallholder farmers economically. Moreover, *Leucaena* trees enhance soil structure and sequester carbon, strengthening the land's capacity to withstand the impacts of climate change, including droughts and severe rains, thus promoting environmental sustainability.

Around the world, "milpa," or intercropping maize, beans, and squash, is used in the Mayan agricultural system on Mexico's Yucatan Peninsula. According to Fonteyne et al. (2023), the method fosters biodiversity by minimizing disease outbreaks, improving pest control, and cultivating various crops concurrently. This technique prevents nitrogen depletion by enhancing soil health through a variety of root forms and nutrient requirements. Being the embodiment of traditional ecological knowledge, milpa is also significant from a historical and cultural standpoint. With an intercropping system that emulates natural ecosystems, it can withstand climatic fluctuations better and promote sustainable land use by preserving soil fertility and minimizing the need for chemical inputs.

Similarly, Guatemala's "huertos familiares" (family gardens) combine fruit trees and a variety of crops. Fruit trees' root systems help maintain soil in family gardens, preventing erosion in hilly areas (Pulido et al., 2008). These trees' leaf litter enhances the organic matter and nitrogen cycling of the soil. A wide variety of fruits and vegetables can be found in family gardens, improving household nutrition and food security. Surplus produce can also bring in extra money for the family. These community-managed gardens promote sustainable urban agriculture, integrate traditional knowledge with modern requirements, and strengthen social cohesion and cultural continuity.

4.3 Urban afforestation and reforestation

Urban afforestation and reforestation programs in tropical cities are crucial for promoting biodiversity, reducing climate change impacts, and enhancing urban livability (Hodgman et al., 2012; Locatelli et al., 2015; Windisch et al., 2021). Reforestation restores degraded or deforested areas, while afforestation involves planting trees where none previously existed. These initiatives face challenges, including limited space, conflicting land uses, and urbanization (Mohan et al., 2021). However, they also present opportunities to address air pollution, carbon sequestration, and urban heat island effects (Locatelli et al., 2015). The "City in a Garden" campaign in Singapore, which aims to enhance green cover through tree planting and green space development, is a notable example (Sabri et al., 2023). This initiative underscores the importance of using native tree species, civic engagement, and innovative planting techniques to optimize ecosystem benefits and urban resilience.

Indigenous communities contribute significantly to urban forest restoration by utilizing their customs and traditional knowledge. Because of their intimate connections to local ecosystems, they can provide insightful opinions on native species selection, planting techniques, and sustainable land management (Reyes-García et al., 2018). For instance, indigenous participation in reforestation programs has been crucial in improving biodiversity and restoring degraded landscapes in places like Manaus, Brazil, and Nairobi, Kenya (Welch et al., 2013; MacFarlane et al., 2015; Schmidt et al., 2021; Loch et al., 2023). Through increasing green cover and sequestering carbon, these initiatives not only improve environmental sustainability but also promote community resilience and cultural preservation. Indigenous methods ensure that reforested areas are well-adapted to local conditions, lowering maintenance costs and enhancing long-term survival. Examples of these practices include the selection of native species and traditional planting techniques. Furthermore, by integrating traditional knowledge with modern needs, the participation of indigenous communities in these initiatives promotes social cohesiveness and gives them the power to actively engage in urban development. By taking a holistic approach, urban forest restoration projects become more effective overall and increase the resilience of tropical cities to climate change while protecting cultural heritage.

Challenges in scaling indigenous-led afforestation and reforestation initiatives include navigating regulatory frameworks, managing competing land uses, and securing land tenure rights for indigenous populations (Melo et al., 2013). Project scalability is further hampered by limited access to funding, technical support, and capacity-building resources (Melo et al., 2013; Nunes et al., 2020).

Opportunities to overcome these challenges include collaborative partnerships among governments, indigenous groups, and civil society to build capacity, share knowledge, and mobilize resources (Melo et al., 2013). Project designs that integrate indigenous knowledge systems and practices can optimize ecological sustainability and community engagement (Davis et al., 2012). International funding mechanisms like REDD+ (Reducing Emissions from Deforestation and Forest Degradation) have the potential to provide financial support for indigenous-led forest conservation and restoration efforts (Nunes et al., 2020).

However, it is crucial to acknowledge that the benefits of REDD+ for indigenous communities are not universally guaranteed. Research indicates that while REDD+ can offer financial incentives, it may also pose risks such as land tenure conflicts, inequitable benefit sharing, and the undermining of indigenous rights and governance systems (Milne et al., 2019). Thus, careful consideration and inclusive, participatory approaches are necessary to ensure that REDD+ initiatives genuinely benefit indigenous populations and do not worsen existing vulnerabilities. By addressing these challenges and leveraging opportunities through inclusive and equitable frameworks, it is possible to enhance climate resilience, biodiversity conservation, and sustainable development in tropical cities.

4.4 Innovations in waste management practices and indigenous technologies

Indigenous communities in tropical cities have developed innovative waste management methods to mitigate climate change by reducing greenhouse gas emissions and promoting resource recovery (Senekane et al., 2022; Octaviani et al., 2024). One such method is composting, where organic waste decomposes to create nutrient-rich compost for soil improvement (Ayodya et al., 2023; Octaviani et al., 2024). In cities like Accra, Ghana, community-based composting facilities treat organic waste from households and markets, reducing methane emissions from landfills and enhancing soil health in urban agriculture (Abalo et al., 2018; Vinti and Vaccari, 2022). Vermiculture, another traditional method, uses earthworms to break down organic waste and produce vermicompost. Community-led initiatives in cities like Bangalore, India, have introduced vermiculture systems in residential areas and urban gardens, diverting organic waste from landfills and producing high-quality organic fertilizer (Babu et al., 2023; Thirunavukkarasu et al., 2023). Barton (2018) argued that the revival of such practices can be attributed mainly to the contemporary worldwide sharing of waste management ideas and their history as colonies.

Furthermore, traditional methods are used to recycle waste materials into useful products (Bernardo, 2008; Asim et al., 2012; Kodiya et al., 2023). Informal waste collectors, or "scavengers," in Manila, Philippines, gather recyclables from landfills and streets, sort them, and sell them to recycling centers (Bernardo, 2008). This informal recycling industry reduces waste accumulation and supports local livelihoods and economies. Similarly, in Salvador, Brazil, artisans known as "catadores" use traditional knowledge to repurpose waste materials like glass, plastic bottles, and tires into handicrafts and artwork, promoting economic empowerment and environmental awareness (Coletto, 2010; Millar, 2014; Carbonai et al., 2023).

An indigenous innovation named the Black Soldier Fly (BSF) is being utilized increasingly in tropical cities for managing waste and reducing the effects of climate change (Mertenat et al., 2019; Surendra et al., 2020; Amrul et al., 2022; Octaviani et al., 2024). Organic waste is effectively consumed by BSF larvae, who use it to produce high-protein biomass and nutrient-rich fertilizer. By cutting the demand for chemical fertilizers and reducing methane emissions from landfills, this approach helps to promote sustainable agriculture and mitigate climate change (Surendra et al., 2020). BSF systems are used in community composting initiatives and organic waste treatment facilities in cities like Bangkok, Thailand, and Lagos, Nigeria. They provide a scalable and environmentally sound alternative to problems with urban waste management (Baiano, 2020; Tamasiga et al., 2022).

These examples illustrate how contemporary urban waste management practices in tropical cities can draw from both indigenous traditions and community-based innovations, contributing to sustainability and climate resilience.

4.5 Raising awareness and educating

In order to empower people to reduce greenhouse gas emissions as well as enhance indigenous understanding of climate change, educational programs in tropical cities are essential (Vize, 2012). Such initiatives usually focus on fusing scientific ideas with indigenous knowledge systems to promote a thorough understanding of the impacts of climate change and strategies for adaptation (Nyong et al., 2007; Mistry and Berardi, 2016). Community-based climate change education initiatives that involve youth, elders, and indigenous leaders in sharing knowledge and capacity building is one example. Community-led workshops, storytelling sessions, and participatory mapping exercises promote discussion and learning about local climate change impacts and traditional coping mechanisms in cities such as Manaus, Brazil, and Dar es Salaam, Tanzania (Theodory, 2020; Canova et al., 2023).

Additionally, educational initiatives promote sustainable measures including managing waste, agroforestry, and renewable energy, enabling indigenous people to take steps to reduce their carbon footprint (Demssie et al., 2020). Indigenous-led environmental education centers enable communities to become stewards of their natural resources and advocates for climate action in cities like Jakarta, Indonesia, and Iquitos, Peru. These centers offer training on eco-friendly technologies, sustainable agriculture, and forest conservation (Swierk and Madigosky, 2014; Daniel et al., 2022; Gani et al., 2023).

5 Conclusion and recommendations

Tropical city ICCMSs are important and successful means of tackling the many problems that climate change has to offer. These approaches, which draw from cultural norms, traditional knowledge systems, and engagement in the community, provide broad and strategically appropriate remedies that improve social justice, sustainability, and resilience. By means of practices like agroforestry, sustainable urban agriculture, afforestation, reforestation, waste management, and education, indigenous groups are contributing to the protection of biodiversity and reducing greenhouse gas emissions, cultural continuity and food security. To fully utilize ICCMSs and promote inclusive and equitable climate action in tropical cities, it is crucial to define and frame concepts like urban indigeneity and indigenous urbanism within the context of the Global South. This involves integrating indigenous knowledge into policy frameworks, urban planning, and development projects. Investing in indigenous-led initiatives and conducting further research are necessary for tackling the critical problems of climate change in a world that is rapidly urbanizing.

In light of the study's findings, the following recommendations are made for governments and international organizations:

- Increased collaboration with indigenous communities to recognize traditional practices and apply them to waste management, the development of green infrastructure, and urban planning regulations. Through integration, sustainable development that is adapted to local conditions will be promoted and region-specific solutions will be utilized;
- Boost the amount of funds, technical assistance, and capacity-building support given to indigenously led initiatives in afforestation, reforestation, sustainable agriculture, and waste management. To support indigenous communities in their efforts to mitigate the effects of climate change, this includes providing financial support for community-based projects, educational initiatives, and knowledge-sharing networks;
- Uphold the rights of indigenous communities to land tenure and include them in the planning and decision-making processes related to land use. Create community land titles, acknowledge and protect indigenous land rights, and bolster governance frameworks to enable their meaningful involvement in climate adaptation and natural resource management;

- Establish organizations and financial tools, such as Green Climate Funds and Indigenous Peoples' Funds, to support and give priority to projects led by indigenous peoples that mitigate climate change. With this focused funding, it will be making sure that funds are distributed wisely to projects that make use of local knowledge and practices; and
- Develop resources for learning, workshops, and public awareness initiatives that emphasize the contribution of indigenous people to the adaptation and mitigation of climate change. Through these efforts, the public will be more receptive to indigenous ideas on sustainability and environmental stewardship, which will strengthen the case for indigenous-led climate action.

Data availability statement

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

Author contributions

TA: Conceptualization, Investigation, Methodology, Project administration, Visualization, Writing – original draft, Writing – review & editing. TO: Conceptualization, Methodology, Supervision, Visualization, Writing – review & editing. AA: Validation, Visualization, Writing – review & editing. MF: Project administration, Visualization, Writing – review & editing.

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Conflict of interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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