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Urban climate adaptation and mitigation action plans: A critical review

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ABSTRACT

Local governments are expected now more than ever to lead climate action planning as climate change intensifies and urbanization increases rapidly. However, studies indicate limitations in the comprehensiveness and level of integration of adaptation and mitigation in existing climate action plans. To develop suitable climate action plans that are comprehensive and consistent with globally accepted standards and benchmarks, this study proposed an Urban Climate Action Planning framework and pilot-tested it with 257 urban climate action plans. Overall, 43 criteria are included in the framework across three stages of climate planning. The pilot test revealed that more than half of the sampled plans have a medium level of suitability, with 39% having a weak level of suitability. About 51% of plans from Europe have a weak level of suitability. Surprisingly, none of the plans sampled from Africa and Latin America achieved a weak level of suitability despite lacking a significant share of global climate research and development funding. A Kruskal-Wallis test shows a statistically significant association between stages of climate planning and (a) city types (p-value of 0.004326) and (b) year of adoption or publication of climate plans and suitability scores (p-value of 0.0001027). Urban climate action plans adopted or published more recently (2018–2022) are likely more suitable than those adopted or published earlier. The sampled urban climate action plans from the Global South had higher average suitability scores than those from the Global North. The study presents key findings and considerations for urban climate action planning and future research.

1. Introduction

The most significant trend of urban growth is currently happening. More than half of the world's population presently resides in urban areas, with an estimated 68% urbanized population by 2050 [1]. At the same time, urban areas are the most exposed and vulnerable to a changing climate and its associated hazards, including heatwaves, floods, storm surges, and other natural hazards [2,3]. These phenomena have invigorated the necessity to move beyond the "business as usual" approach to achieving sustainable urban development. For instance, recent reports have highlighted the need for urgent urban climate actions to drastically reduce greenhouse gas (GHG) emissions and develop systems for climate adaptation [4–6]. The more cities plan and implement actions to reduce GHG emissions, the closer the world moves to achieving the Paris Goals. This is because cities are responsible for over 70% of global GHG emissions and consume more than two-thirds of the world's energy [7,8].

The role of local governments in climate action planning has become more renowned amidst climate change and rapid urbanization [9–11]. Most local governments have greatly emphasized addressing climate change and ensuring sustainable urban development, at least since the inception of the Paris Agreement and the Climate Summit for Local Leaders in 2015 [12]. For instance, more than 100 cities participating in the 2019 United Nations Climate Action Summit announced various steps to address the climate crisis [13]. Also, other city governments have become members and signatories to different international climate networks and initiatives, where they commit, collaborate, and deliver actions to confront the impacts of climate change [11,14,15]. Established literature highlights how cities respond to climate change by developing climate action plans (CAPs) [10,14,15]. Urban CAPs detail city-level visions, targets, and actions for mitigation and/or adaptation [16]. While mitigation actions reduce the sources or enhance GHG carbon sinks [17], adaptation efforts limit vulnerability and increase the coping capacity towards adjusting to actual or expected climate and its effects [17,18]. This shows that developing urban climate action plans is a significant initial step in addressing city-level climate change. However, the real test for local governments lies in the suitability and implementation performance of the plans through effective actions and measures [19].

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List of abbreviations, including units and nomenclature

BEI	Baseline Emission Inventory
CAPs	Climate Action Plans
EU	European Union
GHG	Greenhouse gas
ICLEI	Local Governments for Sustainability
IPCC	Intergovernmental Panel on Climate Change
UCAP	Urban Climate Action Planning
WAI	Weighted Average Index
GCoM	Global Covenant of Mayors for Climate and Energy
EUCoM	EU Covenant of Mayors

Since 2015, there have been many studies on urban CAPs, particularly assessing the effectiveness of urban climate adaptation actions and GHG emission reduction pledges [6,10,20–22]. For example, Hsu et al. [15] evaluated over 1000 EU Covenant of Mayors (EUCoM)' cities and concluded that 60% would likely achieve their GHG emission reduction targets. Olazabal et al. [6] espoused that most adaptation initiatives in urban CAPs of 59 cities worldwide appear unlikely to be effective. Grafakos et al. [23] also highlighted the extent of the integration of mitigation and adaptation actions in urban CAPs and how this integration can lead to maximizing co-benefits and synergies between climate actions. The effectiveness of mitigation and adaptation actions is closely linked to the availability of comprehensive and integrated models, tools, and frameworks that guide climate action planning [6,24].

The EUCoM's Guidebook for developing Sustainable Energy Action Plans (SECAPs), for example, is one of the first frameworks released to guide local climate mitigation planning [25]. This framework provides local governments with tools for developing policies and actions to meet GHG emission reduction commitments and to conduct baseline GHG emission inventories (BEIs). The updated version of the EUCoM framework presented local governments with mechanisms to conduct risk and vulnerability assessments consistent with the principles of the Global Covenant of Mayors for Climate and Energy (GCoM) also known as the covenant of mayors [26]. This revised edition, released in 2018, particularly emphasizes on the need for considering key principles, including stakeholder consultation and engagement, effective climate governance, coordination between departments, data gathering and processing, monitoring and evaluation, and financing in local climate action planning [26]. A standardized reporting framework for local governments across the world was also launched in 2019 by the GCoM. The GCoM Common Reporting Framework presents recommendations for city-specific effective climate action planning, implementation and tracking, strong local climate and energy governance, and technical and financial support [27].

Few guiding frameworks from other international climate organizations such as C40s, ICLEI, and UN- Habitat also exist for city-level climate action planning [28–31]. In addition, efforts by previous studies [2,11,20,32,33] to propose frameworks to support local climate action planning are established in the literature. These frameworks mainly provide guiding principles and indicators for climate action planning. Yet, evidence exists that urban CAPs and climate action planning approaches are not comprehensive and lack the incorporation of emerging sustainability and climate-related concepts and criteria. For instance, a study by Swanson [34] revealed the absence of equity in various adaptation-planning processes. Examining plans from a different perspective, Grafakos et al. [23] found that most existing urban CAPs lack a careful consideration of actions that may result in potential multiple climate benefits. Sheehan et al. [32] also assert that urban health adaptation strategies, a critical factor in the face of health pandemics, are missing in most climate adaptation planning efforts of large cities. The mainstreaming of sustainability issues (particularly the Sustainable Development Goals), technological advancement, innovative governance, and feasible financing solutions in climate action planning appear less visible in existing climate action plans. The IPCC's Sixth Assessment Report on Mitigation of Climate Change [35] explicitly suggests considering these critical elements in future climate action planning. Ultimately, the existing frameworks are limited in supporting integrated climate action planning (that is, considering the integration of mitigation and adaptation actions) and/or non-exhaustive to include emerging climate and sustainability elements in urban climate action planning. Moreover, while most past studies primarily focus on assessing the credibility of the climate action planning process, the scope and perceived outcomes of urban CAPs (often referred to as effectiveness, relevance or quality of urban CAPs) [6,36–38], none presents scientific evidence on the extent to which the contents of urban CAPs consider emerging and well-established climate action planning criteria, standards, and benchmarks (referred to as suitability of urban CAPs in this study) across the globe. The study hypothesize that a suitable plan is likely to be cost-effective and applicable to achieve the climate objectives of a city. Thus, suitable plans incorporate relevant criteria of urban climate action planning and are consistent with globally acknowledged urban climate action planning standards, criteria, and benchmarks.

This study, therefore, proposes an integrated and comprehensive urban climate action planning framework to guide the development of suitable CAPs. In practice, the framework will serve as a tool for developing city-specific CAPs consistent with acceptable climate action planning standards and benchmarks. Cities have become the cause and solution of global climate change; hence, the integration and comprehensiveness in urban climate planning reduce maladaptation and achieve multiple benefits in climate action implementation. Suitable urban CAPs will, therefore, contribute immensely to global, regional, and national emission reduction commitments, cleaner production, sustainable energy consumption, disaster preparedness, and achieving many of the Sustainable Development Goals, particularly goal 13 – climate action. The framework's scoring criteria are also presented to evaluate the suitability of urban CAPs. This study's proposed framework, so far, will be the most integrated (allows for the integration of mitigation and adaptation planning) and comprehensive (far-reaching to enable the inclusion of existing criteria from previous frameworks and emerging climate and sustainability elements necessary for urban climate action planning) guiding tool for urban climate action planning and suitability assessment. Accordingly, this study's main objectives are to develop an integrated and comprehensive urban climate action planning (UCAP) framework and adopt the developed framework to pilot-test the suitability of 257 urban CAPs worldwide.

The development of the UCAP framework encompasses approaches in relevant existing climate action planning tools. The study will also include emerging concepts from academic studies to enhance the comprehensiveness of the framework. The study is subsequently structured as follows. Section 2 reviews existing scientific studies on urban climate action planning and relevant local climate action planning frameworks. Section 3 introduces the developed UCAP framework. Section 4 provides the results of the suitability assessment, and section 5 broadly discusses the results in the context of existing literature. Concluding remarks and areas for future research are presented in the last section.

2. Exploring urban climate action planning: an overview of scope and existing frameworks

City leaders have shown much commitment to climate action planning over the years. Studies have shown that urban climate action planning began around the late 1990s [20,39]. The growing number of international climate initiatives has increased urban climate action planning. For instance, the C40 Cities Climate Leadership Group, a global network that collaborates with city actors toward urban climate action planning, increased its network membership from 19 cities in

2010 [40] to about 100 cities as of 2021 [41]. Similarly, there has been an increase in the number of cities' climate actions disclosed in CDP (previously the Carbon Disclosure Project) from 48 in 2011 to about 1100 in 2021 [42]. City governments' climate actions are commonly embedded in the city's CAPs, developed through various climate action planning processes.

The importance of urban CAPs in reducing GHG emissions and adapting to the impacts of climate change is well documented [15,20,21]. There has been a varied focal point in urban CAPs assessments. Studies have primarily focused on the effectiveness of adaptation [6,27,34–36] or mitigation plans [14,15,22,43–45]. The effectiveness of urban CAPs has mainly been referred to as evaluating the credibility of the planning processes, the scope of actions and measures and whether the nature of the plans will result in expected climate adaptation, energy consumption, or overall GHG emission reduction targets. Other recent studies have also analyzed the significance of urban CAPs focusing on achieving specific climate benefits [20,46]. Although these studies provide a solid background to understand the potential impacts of existing urban CAPs, none extensively explored the extent of integration between mitigation and adaptation actions in urban CAPs like the work of Grafakos et al. [11,23]. Grafakos et al. [23] found that most plans from EU cities have a "moderate" level of integration. This means that most CAPs from EU cities mainly consider GHG emission sources and vulnerability profiles separately and, to some extent, identify potential synergies for mitigation and adaptation actions. While Grafakos et al. [23] overly focused on the integration level between adaptation and mitigation actions in urban CAPs, recent studies have shown that effective climate action planning transcends merely the interrelationships between adaptation and mitigation actions. The consideration of other climatic and sustainability elements, such as equity, is considered relevant in modern local climate action planning [34,47]. Again, studies have revealed various conceptual and institutional weaknesses in urban CAPs, underscoring attention to existing local climate action planning approaches [48,49]. Despite the significance of considering future climate risk [17] in climate decision-making, Singh et al. [50] revealed that most Indian cities develop adaptation actions to address short-term risks due to limited information on the uncertainties of climatic impacts in the long term. These inconsistencies are primarily attributed to inadequate integrated and comprehensive guiding frameworks to plan, implement, and evaluate climate actions [6,15,51].

A growing number of studies and international climate-focused institutions have proposed frameworks and tools to guide local climate action planning. Others have also suggested criteria to ascertain the perceived effectiveness of existing urban CAPs. As a case in point, a study by Pizzorni et al. [2] suggested a methodological framework to evaluate the urban content in National Adaptation Plans. In the same way, the works of Tyler & Moench [33] and Sheehan et al. [32] presented a guiding framework to improve the effectiveness of urban climate adaptation planning. Conversely, Azevedo & Leal [21] proposed an analytical framework for measuring the extent to which prevailing approaches can effectively assess local climate mitigation actions. These frameworks only support urban climate mitigation and adaptation planning in isolation, limiting the tendency for urban areas to maximize co-benefits and synergies from integrating mitigation and adaptation in their climate planning processes [52]. The pressing demand to confront climate change at the city level has coincided with the release of local climate mitigation and adaptation planning frameworks from international climate-related networks. Key among these frameworks include the UN-Habitat Guiding Principles for City Climate Action Planning, the EUCoM Guidebook to develop SEAP and the SECAP, and the GCoM Common Reporting Framework. The UN-Habitat framework, for instance, provides eight context-based principles for city climate action planning [53] while the EUCoM and GCoM frameworks recommend elements to be considered in local climate adaptation and mitigation planning from initiation and scoping to monitoring, reporting, and communication [26,27]. However, none of the existing frameworks from these international climate organisations and previous studies present a scoring system to guide the quantitative assessments of the suitability of urban CAPs.

For example, studies by Rivas et al. [54] and Palermo et al. [55] reveal how the majority of local governments within the EU region leverage essential climate planning criteria such as climate governance and regulations, education and awareness, financing and budgeting, and stakeholder engagement and involvement in the covenant of mayors climate planning framework to achieve their energy consumption and GHG mitigation targets despite the existence of technical and financial barriers across city types (mainly among small and medium cities). However, little is known about the explicit level of suitability of the plans to the overall criteria in the covenant of mayors' framework. This is perhaps due to the absence of a standardized suitability scoring system in the framework. The existence of these frameworks demands critical inquiry about whether the contents of urban CAPs are suitable, hence, demanding an answer to the question: are urban CAPs incorporating relevant criteria for urban climate action planning and what are the dynamics across the global divide and city size?

Two distinct frameworks with a scoring system are introduced in the works of Tieopolo [20] and Grafakos et al. [11].Although these scoring systems were not presented for suitability analysis, these frameworks emphasize relevance of measures and the need for integrating actions that lead to mitigation and/or adaptation benefits. For example, an indicator in the Quality of Climate Plans Index developed by Tieopolo [20] defines the relevance of measures in urban CAPs as having the capacity to reduce GHG emissions or climate risk significantly. Also, Grafakos et al. [11]'s Urban Climate Change Integration Index framework specifically provide indicators for investigating the extent of integration of adaptation and mitigation within the three stages of local climate planning. The three stages in urban climate planning (identifying and understanding stage (i), envisioning and planning stage (ii), and implementation, management, and monitoring stage (iii)), as suggested in the Urban Climate Change Integration Index, offer considerable insights to guide local climate action planning [11]. However, the Urban Climate Change Integration Index and Quality of Climate Plans Index are inadequate in considering evolving components and concepts of urban climate action planning, emphasizing the need for a more integrated and comprehensive framework. More specifically, the frameworks failed to appreciate critical climate action planning elements such as extensive stakeholder engagement, climate exposure profiling, the extent of deep decarbonization pledges, and accountability and learning in local climate action planning. Similarly, Otto et al. [46] proposed a framework to rank urban CAPs based on their level of integration of mitigation and adaptation. However, the framework paid little attention to the context and process of mitigation and adaptation action and implementation planning [56].

This research leverages and contributes to existing scientific studies by proposing a more integrated and comprehensive framework to guide urban climate action planning and assess the level of suitability of urban CAPs. The framework will be a mechanism to enhance quality, cost-effective, and proactive urban climate action planning. In this study, the framework will be adopted to pilot-test the suitability of 257 urban CAPs from world cities. This research will also analyze urban CAP suitability by city types and across the global divide. This study will provide policymakers, researchers, and urban planners with the critical elements necessary to develop suitable CAPs consistent with current urban climate action planning standards and benchmarks in the face of climate extremities.

3. Materials and methods

3.1. Developing the urban climate action planning (UCAP) framework

The UCAP framework is developed with criteria drawn from the syntheses of recent scientific studies on climate action planning, current benchmarks for climate action planning, and existing urban climate action planning frameworks. Eight major steps were followed to develop and pilot-test the framework. Fig. 1 illustrates the flowchart for developing the framework and application for the pilot testing.

In the first step, the study conducted a review of the literature on urban climate action planning and frameworks for assessing and ranking climate plans. Related literature included in the review was downloaded from the "Web of Science", "Scopus", and "Google Scholar" databases. Supplementary Appendix 1 presents the literature review process and the search string. The research also reviewed climate action planning benchmarks and variables from published reports and working papers. This process included a review of existing climate planning frameworks from international climate-related bodies such as ICLEI, C40s, the European Commission (Climate-Neutral and Smart Cities Mission), the World Resource Institute, and the UN-Habitat. The importance of the review was to assess the scope, gaps, and recent critical elements for climate planning. The second step involved identifying potential criteria from the documents reviewed in the first step. The findings from the review, particularly the gaps and emerging variables for climate planning, influenced the identification and comprehensiveness of the criteria in the framework. The potential criteria identified were further validated against set inclusion and exclusion standards. The included criteria must be the following standards:

(a) Criteria should be explicitly embedded in previous frameworks and benchmarks
(b) Criteria should have a definite focus on urban climate action planning
(c) Criteria should contribute to the integration and comprehensiveness of future climate action plans (more emphasis placed on suggested criteria in recent literature and reports, particularly from IPCC and the UN-Habitat)
(d) They should include clear, well-defined variables necessary for climate action planning (For example, ambiguous criteria were excluded). However, the study adopted a careful review process that allows for the inclusion of undefined but relevant and applicable criteria necessary to evaluate the suitability of plans pertaining to specific thematic areas/categories (such as mitigation, adaptation, policy recommendations, equity, and future pandemics). These criteria were defined based on further literature review and included in the framework to ensure the robustness and comprehensiveness of the framework while limiting potential bias in the criteria selection.
(e) Relevant criteria that fill a gap in urban climate action planning, as espoused by previous studies, were included to improve the comprehensiveness of the framework.

The fourth step used the reliability and validation test to define, revise, and finalize the criteria. Finally, 43 criteria were inculcated in the UCAP framework, as seen in Fig. 3. In the fifth step, the research assigned a scoring scale to the finalized criteria to pilot-test the developed framework. Since there are no standard methods for assigning scores for criteria in developed frameworks [57], the study developed the scoring scale for the suitability analysis based on related studies. However, the study ensured that the scoring scale is flexible and can be adopted in different contexts. The study then performed a systematic content analysis on sampled urban CAPs and analyzed their suitability against the developed framework in the sixth and seventh steps. The systematic content analysis process involved deriving reliable and accurate conclusions through the extraction, categorization, and examination of text data obtained from the sampled urban CAPs. This process offers a systematic approach to analyzing themes and patterns from textual data. While systematic content analysis has been criticized for being basic and oversimplified with a lack of rigor and in-depth results [58], methodological robustness is enhanced by converting the qualitative data extracted and coded through a guided and systematic process from the urban CAPs into quantitative analysis. The trends and patterns captured through the content analysis provide new insights, understanding, and interpretations for evaluating the level of suitability of urban CAPs across city types, regions, and the global divide [59]. The systematic content approach has been frequently used in recent climate planning research [23], probably due to its ability to help

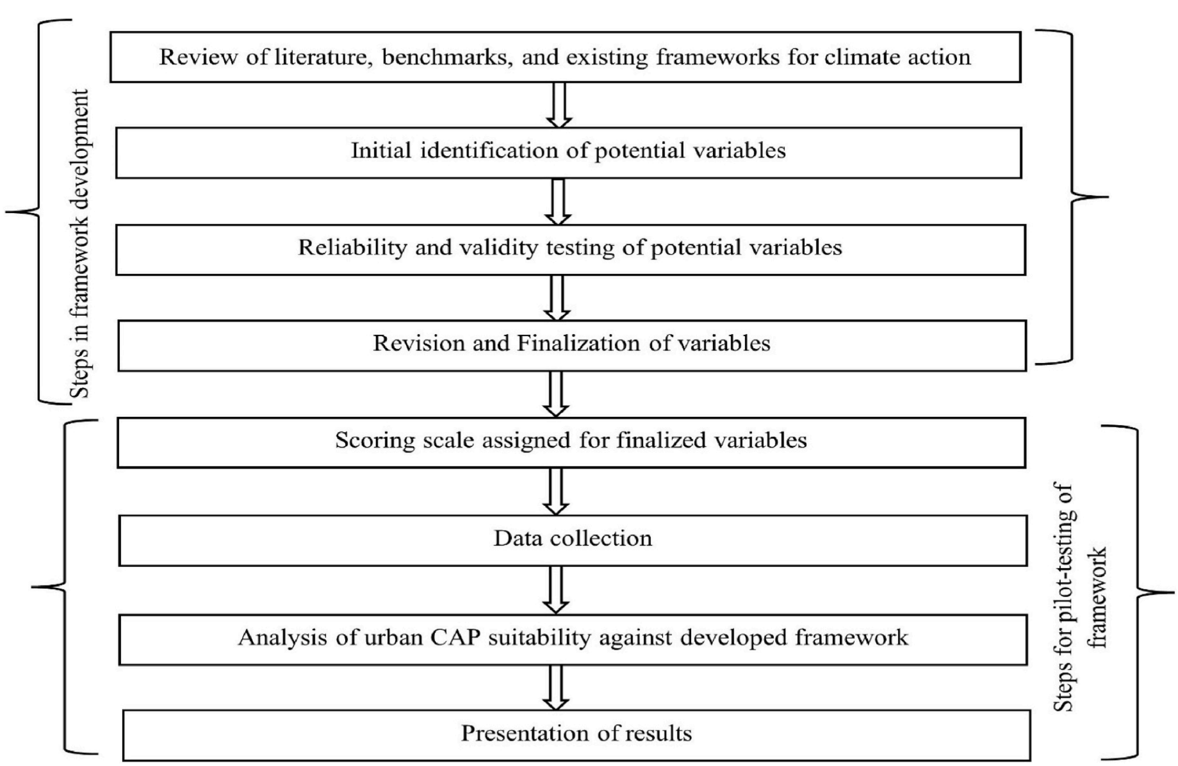


Fig. 1. Flowchart in framework development and application for pilot testing.

researchers in uncovering underlying actions, measures, and strategies embedded in climate planning documents. Section 3.2 of this study presents details of the urban CAP suitability assessment. The final step is the application of results from the pilot test.

The urban climate action planning (UCAP) framework is displayed in Fig. 2. The framework presents three stages in urban climate planning adapted from Grafakos et al. [11]. These stages include (1) identifying and understanding, (2) envisioning and planning, and (3) implementing and monitoring. The "**identifying and understanding"** stage initiates the local action planning process. It provides scientific evidence and situation analysis to inform climate actions and measures. The **"envisioning and planning"** stage involves setting the city's climate vision, targets, and actions. In modern local climate action planning, extensive stakeholder engagement is essential at this stage [49]. This stage also demands plans to communicate and enhance citizens' awareness and knowledge of climate vision, targets, and actions. According to Grafakos et al. [11], the **"implementation, management, and monitoring"** stage guides decision-making toward implementing, monitoring, and evaluating climate actions. This stage follows that remarkable consideration should be given to financing commitments, resource estimations (for example, human resources and budget), and possible funding sources at this stage [11,60]. Also, issues concerning institutional and regulatory frameworks are necessary when implementing climate actions [11]. The indication of an implementation plan or schedule, a governance structure, and monitoring and evaluation indicators have also turned out to be critical criteria for this stage. An implementation plan or schedule presents the specifics for each climate action, including responsibilities, estimated cost, and projected timeline to implement each action [61]. It is also important for decision-makers to plan for reporting and stakeholder feedback at this stage. Additionally, the explicit consideration of monitoring and evaluation indicators in urban CAPs improves the monitoring, evaluation, and accountability of climate actions as well as assists funders and other stakeholders in independently measuring the impacts of their investments [51]. A clear governance structure for climate action implementation enhances the transparency and inclusiveness of the planning process.

3.2. *Urban CAP suitability assessment*

The study conducted a systematic content analysis of 257 urban CAPs worldwide to test the suitability of urban CAPs using the developed UCAP framework. The assessment was based strictly on the content of the sampled urban CAP. It is worth noting that limiting the analysis to just the content of the sampled urban CAPs might probably affect certain cities' actual climate planning efforts since most cities have separate documents targeted at climate governance, monitoring and evaluation, and budgets. However, in an attempt to analyze the integratedness and comprehensiveness of urban CAPs, this study assumes that a suitable plan must include all necessary strategies and a roadmap for climate action and implementation planning. Two phases were followed in retrieving urban CAPs for the study. The research began by downloading urban CAPs submitted to websites of relevant global climate networks, including ICLEI-Local Governments for Sustainability, C40, the GCoM, Zero Energy Project, and Resilient Cities Network. In the second phase, the research used a search string to manually search Google.com. The search string (Supplementary Appendix 2) combined "city name" and synonyms of "climate action plan":

The first phase of the search was conducted from October 2021 to December 2021. The second phase of the search was performed from April 2021 to December 2022. The primary inclusion criteria for downloading the CAPs were:

(a) CAPs that were adopted and published after 2014
(b) CAPs that belong to a geographical area that can be termed a "city" or an "urban area" as defined by UN-Habitat [62] and
(c) CAPs that were published in the English Language.

The two phases returned 278 urban CAPs. However, 21 urban CAPs downloaded were published in their summarised versions and did not provide enough information for a broader analysis; hence, they were excluded from the study. In the end, 257 urban CAPs were relevant for the final study. The contents of the urban CAPs were systematically reviewed and evaluated according to the developed UCAP framework. The data was coded based on the scoring scale of the proposed UCAP framework (Supplementary Appendix 3). The coding was performed by one analyst using a two-step approach. The process involved conducting

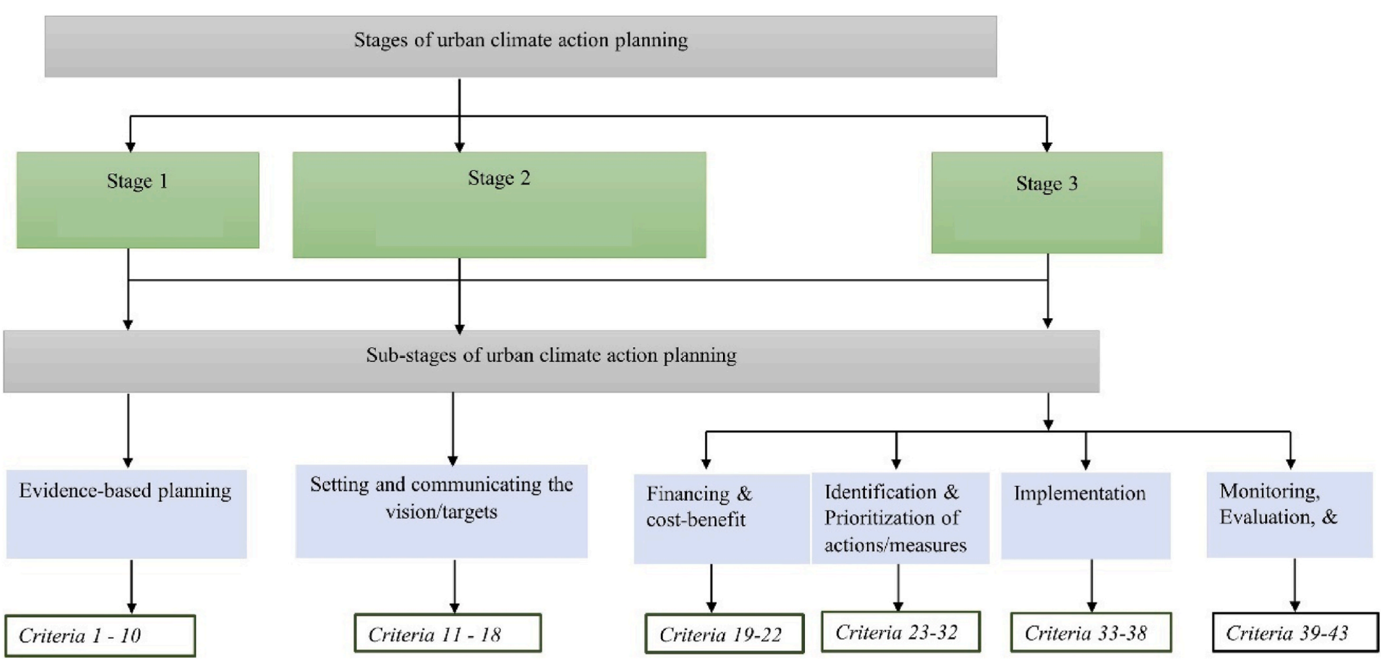


Fig. 2. The Urban Climate Action Planning (UCAP) framework.

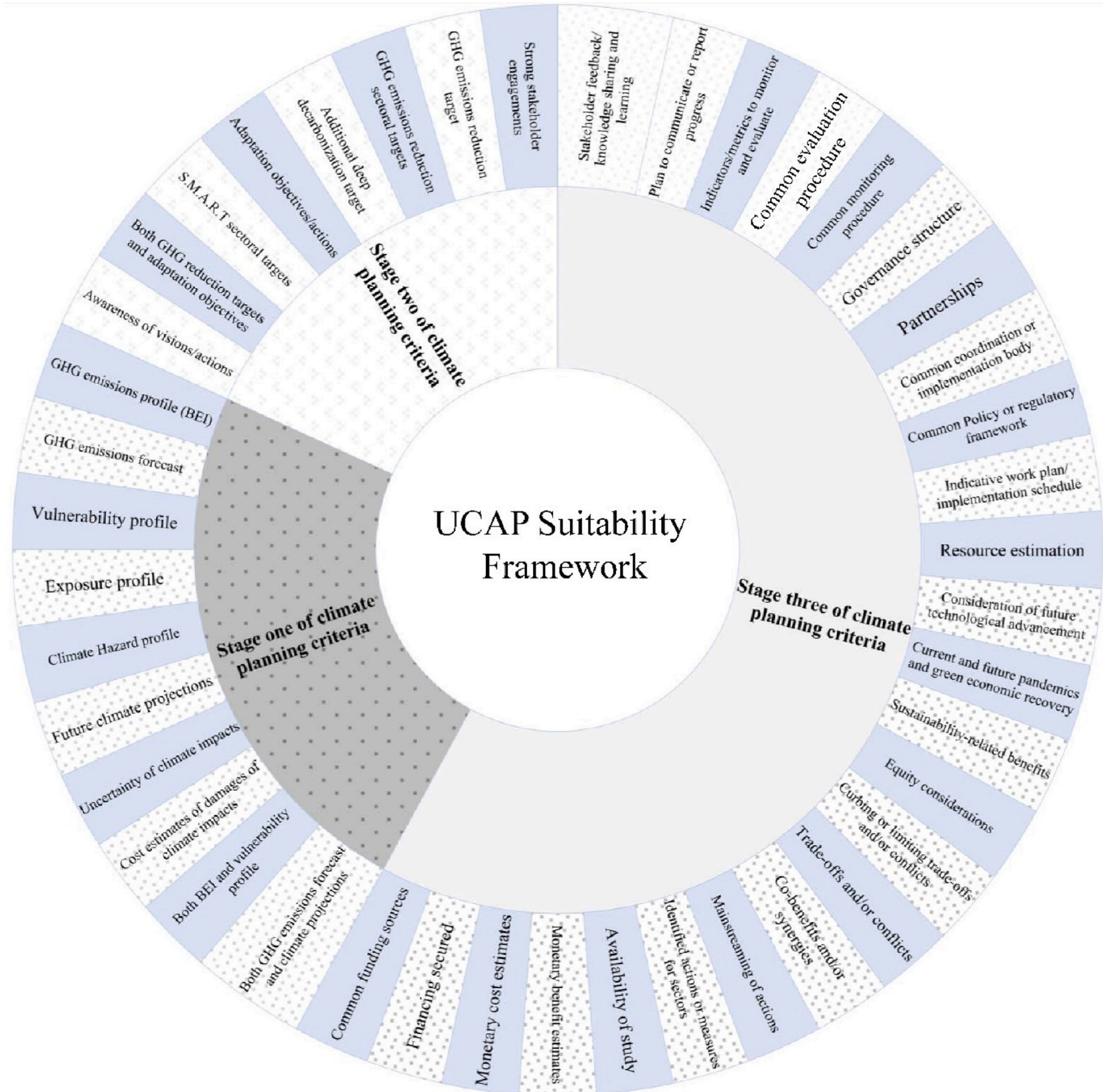


Fig. 3. The UCAP framework stages and criteria.

an initial coding and checking the data set for consistency and accuracy against the assigned and agreed codes. The study used descriptive statistical analyses to present the study's results. The analyses clustered the sampled cities into various typologies, specifically city sizes and political and socio-economic characteristics (Global North and South divide). Table 1 presents the list of sampled cities according to their city sizes. The study categorized the city sizes into small, medium, large, and megacities based on Lamb et al. [63] and Aboagye & Sharifi [64]. Population statistics from Ref. [65] were used to categorize the sampled cities into various sizes. The Global South – Global North categorization was based on Kowalski [66].

The suitability analysis involved assigning scores to each variable in

Table 1
List of sampled cities according to city sizes.

City type	Definition	Number of urban CAPs
Small City	Population of less than 300,000	150
Medium City	300,000–1 million population	57
Large City	Population of 1 million – 10 million	41
Megacity	over 10 million population	9
Total		**257**

the framework. Supplementary Appendix 3 also provides a detailed explanation of the criteria used for the framework. Twenty-five criteria were assigned binary scores of 0 and 1 because they returned "yes" or "no" answers. (Supplementary Appendix 3 – green color). At this level, considered criteria that returned a "yes" answer earn a score of 1 for the urban CAP. In contrast, non-considered criteria will return a 0 score for the urban CAP. Moreover, 18 criteria were assigned a scoring scale between 0 and 1 based on the degree of consideration in the urban CAP (Supplementary Appendix 3 - orange color). For instance, if an urban CAP scores 1, it means there was a high consideration of the variable (for instance, with clearer and sufficient details). A minimum consideration (for example, just indicating without providing enough details on the variable) will earn the urban CAP a 0.5 score, while a 0 score will be assigned for non-consideration of a variable (Supplementary Appendix 3). This study's scoring system allows for a robust evaluation of the suitability level of urban CAPs while maintaining flexibility in the assessment processes. The stages of the UCAP framework and their criteria are presented in Fig. 3.

The maximum possible score for an urban CAP was 43. The total scores of the urban CAPs were then weighted using the weighted average index (WAI). Most studies have used the WAI to assess the weight of various climate action strategies and practices at the local level [67–69]. In the context of this study, the WAI value was used to rank the "suitability" of each urban CAP. In addition, a five-point categorization range was used to interpret their suitability performance.

The WAI formula is adopted from Gunawan et al. [70]:

$$\text{WAI} = \Sigma \frac{S_i F_i}{N}$$

where F is the response frequency of each variable *i*, S is the score value assigned to the variable *i,* and N is the total number of criteria. Since the frequency of each variable in the UCAP framework is given as one, the WAI of the suitability of an urban CAP could be written as,

$$\text{WAI} = \frac{\sum \text{scores of variables}}{\text{Total number of variables}}$$

The WAI value is given as "$0 \leq \text{WAI} \leq 1$". In assessing the level of suitability of the urban CAPs, a WAI of 1 means that the CAP has a "very strong" suitability; 0.99–0.75 will rank as "strong" suitability; 0.74–0.5 ranks "medium" suitability, 0.49–0.25 means "weak" suitability, and 0 depicts "very weak" suitability. A Kruskal-Wallis non-parametric test was conducted to ascertain possible relationships between stages of climate planning and city types. Here, the study also performed a post hoc Dunn's Test to examine how the three stages of climate planning differ across the various city types. The same tests were conducted to determine whether a statistically significant association and differences exist between the year of adoption or publication of urban CAPs and their suitability scores. Lastly, a non-parametric Mann-Whitney *U* test was carried out on all 257 urban CAPs to determine if there are significant differences between the suitability scores from urban CAPs adopted or published by cities in the Global North and Global South.

4. Results and discussion

The results of the pilot test of urban CAP suitability based on the developed UCAP framework are presented and discussed in this section. As mentioned, the framework's core purpose is to guide the development of suitable urban CAPs. The framework is also necessary to evaluate the suitability of urban CAPs. The initial analysis towards assessing the urban CAP suitability is to evaluate the performance of the urban CAPs across the three stages of planning. As stated in the methodology section, the suitability results presented in this study are stringently limited to the content of the sampled urban CAPs without considering other separate climate planning documents of cities. The assessment of the performance of urban CAPs across the planning stages will be followed by analyzing the scores of individual criteria to ascertain which criteria were largely incorporated and which were largely not incorporated in the sampled urban CAPs. The final section will present results on the total suitability scores of the urban CAPs analyzed.

4.1. Overall scores of urban CAPs across the three stages of climate planning

The overall performance of the 257 urban CAPs across the three stages is highlighted in Table 2. The results indicate that the maximum score obtained by the sampled CAPs is 37 out of a possible 43, with an average score of 22.5. The analysis showed that stage two of climate planning has the highest average percentage score (73%) among the three stages, with stage three having the lowest average percentage score (44.8%).

Across the three stages, Fig. 4 shows that more urban CAPs (60%) scored above the average score of stage two, while almost half (49% - 127 urban CAPs) of urban CAPs analyzed had a score that fell below the average score of stage three of climate planning. Fig. 4 also shows that, on average, stage three of climate planning, which echoes elements for implementing and monitoring climate actions, had the lowest ratings among the three stages of climate planning, with stage two having the highest rating. The reason can be that most local governments still lack the ability to plan effectively for mechanisms needed to finance, implement, monitor, evaluate, and report their climate action plans [6]. This result could also emanate from limitations in this study's methodology since separate climate documents, such as those for climate financing, monitoring, and evaluation, were not considered in this analysis.

There are also variations in scores of the three stages across city sizes, similar to the analysis of climate plans from European cities by Ref. [71]. Table 3 presents the statistical results of the total scores of three planning stages across city types. Almost half of the urban CAPs from medium cities (49% - 28 urban CAPs) and small cities (46% - 69 urban CAPs) performed below the average score in stage one, presuming that quite several cities from these categories do not largely consider a substantial number of criteria under the stage one of climate planning in their urban CAPs. Table 3 also shows that most urban CAPs from megacities (89%), large (73%), medium (60%), and small cities (55%) scored above the average scores in stage two of climate planning as compared to those that scored below the average score of stage two of climate planning.

Notably, the research found a general lack of importance placed on stage three of climate planning among mega, medium, and small cities. More than half of urban CAPs from these city types scored below the average score of stage three of climate planning as presented in Table 3. A previous study by Ref. [6] revealed significant limitations in stage three of climate planning (implementation and monitoring) from climate adaptation plans in large cities across the globe. The evidence in this study, however, stipulates that large cities rather perform better in addressing elements for implementation and monitoring when they are compared to mega, medium, and small cities, with more than two-thirds (73%) of large cities scoring above the average score in stage three of climate planning. The extent to which city types fall below or above the total average scores across the three stages of climate planning is graphically illustrated in Supplementary Appendix 4.

The Kruskal-Wallis test shows a statistically significant association between the stages of climate planning and city types (p-value 0.004326). Similar findings were disclosed by Ref. [8] to the extent that the size of a city may influence the nature of its local climate plans. The pairwise comparison test also indicates significant differences in the average total scores of the three stages of climate planning among some city types. Fig. 5 illustrates the results of a Kruskal-Wallis test and Dunn's post hoc test of city types and their total average scores across all planning stages. The results show that significant differences exist in the average total scores between large and medium cities, with large cities having higher average total scores (adjusted p-value = 0.0169; unadjusted p-value = 0.0028). The comparison between megacities and small

Table 2
Descriptive statistics of total scores across the three stages of climate planning.

	Average scores	Average % scores	Minimum	Maximum	Std. Deviation	Total possible score
Stage 1 of climate planning	5.47	54.70%	0	10	2.61	10
Stage 2 of climate planning	5.84	73.03%	2.5	8	1.35	8
Stage 3 of climate planning	11.20	44.82%	2	21.5	3.34	25
Total scores across three stages	22.51	52.37%	7	37	5.79	43
Total number of cities	257					

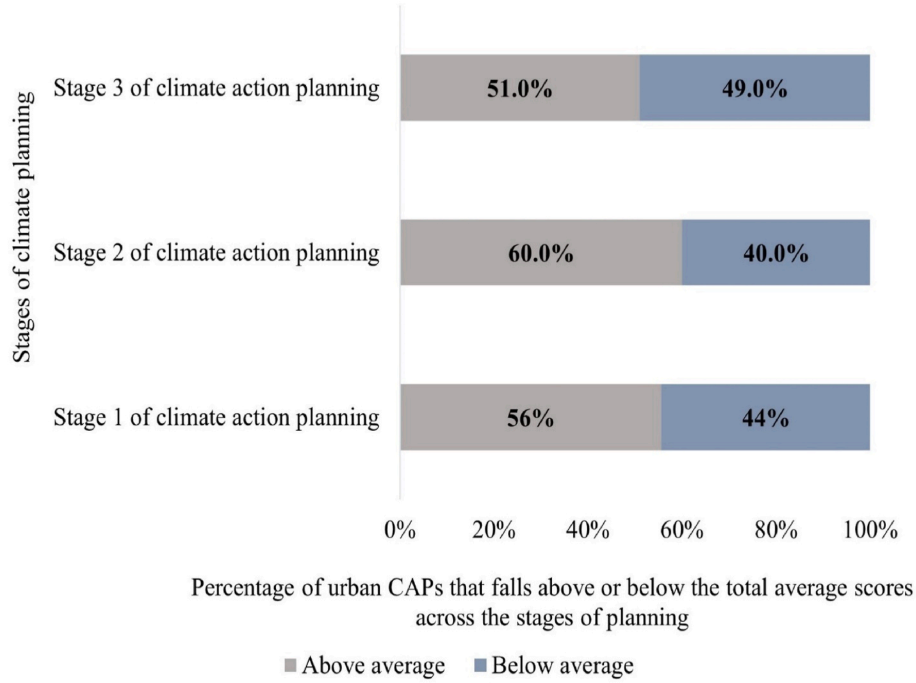


Fig. 4. The extent to which sampled urban CAPs fall above or below the total average scores of the three stages of climate planning.

Table 3
Descriptive statistics of total scores of three stages of planning across city types.

City type		Stage 1 of climate planning					
	Total average score	% > Total average score	% < Total average score	Mean	Minimum	Maximum	Std. Deviation
Megacities (n = 9)	5.47	77.8%	22%	6.55	2	10	2.37
Large cities (n = 41)		63%	37%	6.26	2	9.5	2.53
Medium cities (n = 57)		51%	49%	4.94	0	9	2.7
Small cities (n = 150)		54%	46%	5.38	0	10	2.57
		Stage 2 of climate planning					
City type	Total average score	% > Total average score	% < Total average score	Mean	Minimum	Maximum	Std. Deviation
Megacities (n = 9)	5.84	89%	11%	6.72	5.5	8	0.87
Large cities (n = 41)		73%	27%	6.13	3	8	1.34
Medium cities (n = 57)		60%	40%	5.85	2.5	8	1.29
Small cities (n = 150)		55%	45%	5.70	2.5	8	1.37
		Stage 3 of climate planning					
City type	Total average score	% > Total average score	% < Total average score	Mean	Minimum	Maximum	Std. Deviation
Megacities (n = 9)	11.20	44%	56%	11.55	7	17	3.43
Large cities (n = 41)		73%	27%	12.95	6.5	21.5	3.04
Medium cities (n = 57)		49%	51%	10.89	2	17	3.03
Small cities (n = 150)		45%	55%	10.82	3.5	19.5	3.40
Kruskal-Wallis rank sum test	Chi-Square = 13.149 df = 3 P-Value = 0.004326*						

* Significant at $P < 0.05$.

cities and between large cities and megacities returned p-values greater than 0.05, specifying that no statistically significant difference exists in the total average scores obtained by these city types across the three stages of climate planning.

The results also reveal that large cities performed averagely better in all three stages of climate planning as compared to mega, medium, and small cities as visible in Fig. 5. It can be assumed that, in the long term, local climate plans from large cities are likely to be effective. However, it is worth noting that the analysis of this study was not limited to a specific focus of the CAPs as done by Ref. [6], where they found that adaptation plans in large cities are likely to be ineffective in the long term.

4.2. *Analysis of the consideration of individual criteria*

This section showcases the extent to which individual criteria in the UCAP framework were explicitly considered by cities across the three stages of climate planning. Table 4 depicts the total scores of individual criteria across the three stages of climate planning. In stage one of climate planning, the findings show that the indication of baseline GHG emissions profile has the highest score attaining a score of 238. Evidence on cost estimates of damages of climate impacts was largely not addressed among the sampled urban CAPs (61 of a possible 257), a result consistent with that of [23], which showed that most cities are likely not to inculcate economic costs of damages of climate impacts in their climate plans. The lack of estimation of economic losses inhibits cities' ability to ascertain the degree of the economic cost that they may incur in the event of climate change. Addressing this criterion, the City of Philadelphia, Pennsylvania, clearly stated that an increase in severe weather events and hurricanes is estimated to cost the city between USD $200,000 to USD$2,000,000 while climate-change-induced health impact will cost the city USD$20,000,000 in 2050 (Philadelphia Climate

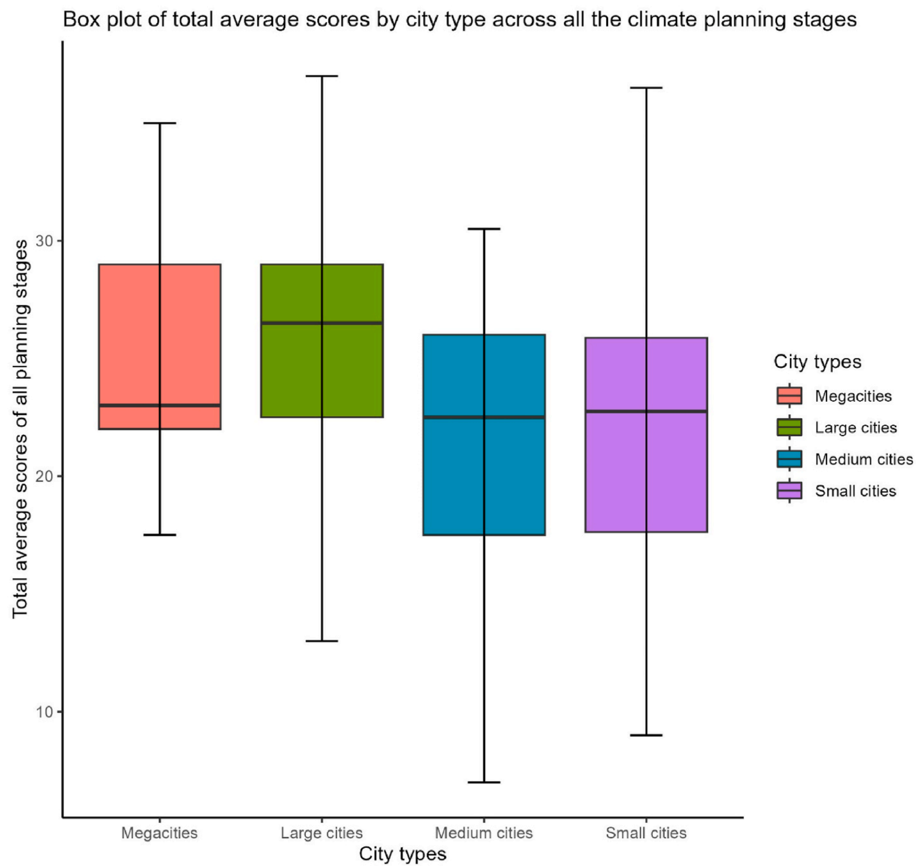


Fig. 5. A Kruskal-Wallis test and Dunn's post hoc test of city types and total average scores of all planning stages.

Action Playbook). Table 4 reveals that the sampled urban CAPs did not largely indicate the uncertainty of climate impacts, confirming the assertion of Filho et al. [72]. Ref. [72] stressed that although uncertainties play a key role in environmental changes, local governments are mostly less informed about the situation, a situation that may hinder decision-making processes and the prioritization of cost-effective climate actions. In addressing risk profiling, as espoused by Thupalli et al. [73], the study found that climate hazard profiling was more emphasized in the sampled urban CAPs than vulnerability and exposure profiling. This suggests that while most cities consider risk assessments in their adaptation plans, the majority pay more attention to indicating their climate hazard profiles than explicitly indicating their vulnerability and exposure profiles.

The explicit indication of GHG emissions reduction targets, enhancing awareness of the city's climate visions and actions, and the inclusion of adaptation objectives and actions are the criteria with the highest scores in stage two of climate planning (249, 248, and 212, respectively of a possible 257) as presented in Table 4. While GHG emission reduction targets gained higher scores in stage two of climate planning, the presence of deep decarbonization targets had the lowest score in the same stage. This finding highlights a pattern of limited deep decarbonization agenda in urban CAPs adopted or published from 2015 to 2022. There is also the possibility that although mitigation is largely championed, deep decarbonization targets are yet to be significantly considered by cities since its urgency is more recent, particularly after the release of the United Nations Environment Programme Emissions Gap Report [5], the IPCC Sixth Assessment Report [35], and decarbonization commitments made at the Conference of Parties 26 [74]. Moreover, the high presence of mitigation objectives (249) over adaptation objectives (212) confirms the high priority that has been given to mitigation over adaptation since the inception of the United Nations Framework Convention on Climate Change, the Kyoto Protocol, and the Paris Agreement [23].

The setting of specific, measurable, achievable, realistic, and time-bound (SMART) targets has recently been established as a key component of climate planning to strengthen the opportunities for local governments to track and achieve long-term results. For instance, a study by Ref. [75] found a positive relationship between the probability of achieving progress in biodiversity plans and the setting of SMART targets. Yet, this study's results reveal that the setting of SMART sectoral targets was largely not addressed in the sampled urban CAPs, obtaining the second-lowest score in stage two. An example of a SMART sectoral target in the sampled urban CAPs is "to develop 15 new pedestrian areas by 2030" under the transportation sector of the CAP 2050 of the City of Buenos Aires.

The results also showed that about 80% (205) of urban CAPs did not explicitly indicate whether finance has been secured for implementing individual climate actions, as depicted in Table 4. This result is similar to that of [6,23]. Just 10% of the urban CAPs mentioned financing commitments secured for individual climate actions with a detailed description of the commitment (including source and actual value of funding secured). In addition, less than half (48%) of the sampled urban CAPs largely indicated proposed common funding sources for the implementation of the plan. Common funding sources indicated by the sampled cities include internal government/city budgets, private sector investments, public-private partnerships, market-based approaches, internally generated funds, green climate funds, funding from international partners (national governments, C40s, EU, etc.), and other external sources from bilateral and multilateral donors. The analysis revealed that most cities tend to explicitly indicate the monetary costs of proposed climate actions (110) over the explicit incorporation of estimated monetary benefits of proposed climate actions (66). According to Ref. [76], such results could lead to inefficiencies in public expenditure and ineffective allocation of resources across various sectors of the city.

The results show that almost all the urban CAPs (99%) identified actions for all their prioritized sectors. Table 4 further reveals that equity, extra sustainability benefits, and the consideration of future technological/innovation advancement were moderately addressed in the urban CAPs with average scores greater than 0.5. The analysis showed that cities tend to achieve extra sustainability benefits by aligning their local climate objectives with other recognized local and international guidelines such as the Sustainable Development Goals and World Health Organization air quality standards. This evidence reflects opportunities for global policymakers and national governments to maximize co-benefits and synergies between urban climate action and equity, sustainable development, and public health (through achieving urban air quality) [77,78]. The analysis further discovered that the consideration of current and future pandemics (such as COVID-19) and strategies for green economic recovery after public health threats was prominent among urban CAPs adopted or published between late 2019 and 2022. Yet, out of the 155 urban CAPs adopted or published within this period, only 33% explicitly considered current and future pandemics and strategies for green economic recovery in their urban CAPs. This finding resonates with that of [32], stressing the urgent need for integrating public health (including current and the possibility of future pandemics) in urban climate action planning. The World Cities Report 2022 also admonishes cities to draw lessons from the COVID-19 pandemic to invest in developing economic, social, environmental, and institutional climate resilience [79].

More cities tend to highlight possible co-benefits and/or synergies (105) that may occur from implementing adaptation and mitigation actions over discussions on future trade-offs and/or conflicts (ten) in implementing climate actions. The study found that most cities that considered trade-offs and/or conflicts are more likely not to suggest possible strategies to curb or limit these trade-offs and/or conflicts. According to Ref. [18], this situation happens due to limited knowledge

Table 4
Total scores of individual criteria across the three stages of climate planning.

Item		Total scores*	% of total urban CAPs scoring 0	% of total urban CAPs scoring 0.5	% of total urban CAPs scoring 1	Mean	SD
Stage one of climate planning		NA	NA	NA	NA	NA	NA
Criteria	GHG emissions profile (BEI)	238	7	-	93	0.92	0.26
	GHG emissions forecast	173	33	-	67	0.67	0.46
	Vulnerability profile	164.5	33	6	61	0.64	0.46
	Exposure profile	90	62	5	32	0.35	0.46
	Climate hazard profile	190	22	9	69	0.74	0.41
	Future climate projections	150.5	38	7	55	0.56	0.47
	Uncertainty of climate impacts	67	74	-	26	0.26	0.43
	Cost estimates of damages of climate impacts	61	76	-	24	0.23	0.42
	Both BEI and vulnerability profile	160	38	-	62	0.62	0.48
	Both GHG emissions forecast and climate projections	113	56	-	44	0.43	0.49
Stage two of climate planning		NA	NA	NA	NA	NA	NA
Criteria	Strong stakeholder engagements	197	13	20	67	0.76	0.35
	GHG emissions reduction target	249	3	-	97	0.97	0.17
	GHG emissions reduction sectoral targets	163.5	30	12	58	0.63	0.44
	Additional deep decarbonization target	112	56	-	44	0.43	0.49
	Adaptation objectives/actions	212	18	-	82	0.82	0.38
	S.M.A.R.T sectoral targets	115	36	39	25	0.45	0.39
	Both GHG reduction targets and adaptation objectives	205	20	-	80	0.80	0.40
	Awareness of visions/actions	248	4	-	96	0.96	0.18
Stage three of climate planning		NA	NA	NA	NA	NA	NA
	Common funding sources	143	37	15	48	0.56	0.45
	Financing secured	39	80	10	10	0.15	0.32
	Monetary cost estimates	110	57	-	43	0.42	0.49
	Monetary benefit estimates of actions	66	74	-	26	0.26	0.43
	Availability of study	154.5	13	54	33	0.60	0.32
	Identified actions or measures for sectors	255	1	0	99	0.99	0.08
	Mainstreaming of actions	232	10	-	90	0.90	0.29
	Co-benefits and/or synergies	105	59	-	41	0.41	0.49
	Trade-offs and/or conflicts	10	96	-	4	0.04	0.19

(continued on next page)

Table 4 (*continued*)

Criteria	Curbing or limiting trade-offs and/or conflicts	4	60**	-	40**	0.02**	0.12**
	Equity considerations	161	37	-	63	0.62	0.48
	Sustainability-related benefits	135	47	-	53	0.52	0.50
	Current and future pandemics and green economic recovery	51***	67***	-	33***	0.20***	0.39***
	Consideration of future technological advancement	171	33	-	67	0.66	0.47
	Resource estimation	65	75	-	25	0.25	0.43
	Indicative work plan/implementation schedule	131	20	58	22	0.50	0.32
	Common Policy or regulatory framework or plan	137	47	-	53	0.53	0.49
	Common coordination or implementation body	226	12	-	88	0.88	0.32
	Partnerships	191	5	42	53	0.74	0.29
	Governance structure	60	77	-	23	0.23	0.42
	Common monitoring procedure	118.5	30	48	22	0.46	0.35
	Common evaluation procedure	44.5	73	18	9	0.17	0.31
	Indicators/metrics to monitor and evaluate	92.5	60	7	33	0.35	0.46
	Plan to communicate or report	142	26	37	37	0.55	0.39
	Stakeholder feedback/knowledge sharing and learning	36	79	14	7	0.14	0.29
	< 0.25	≥ 0.25 and < 0.5		≥ 0.5 and < 0.75			≥ 0.75

*Possible total score is 257 **Calculated out of the total urban CAPs that considered trade-offs and/or conflicts. *** Calculated from CAPs adopted or published from late 2019 to 2022

about the concept of conflicts and trade-offs in implementing climate mitigation and adaptation actions. Less attention to them may result in the futility of integrating climate mitigation and adaptation actions.

The indication of support systems for the actual implementation of climate actions was also analyzed by this study. The results depict that 77% of the urban CAPs did not explicitly indicate a governance structure for the implementation of their climate actions. In the case of resource estimation, the analysis revealed that cities are likely to indicate estimated financial budgets over human resources needed for implementation. In other instances, cities merely propose separate budgets without presenting a detailed breakdown of estimated revenues and expenditures for CAP implementation. A look at the Oakland Equity Climate Action Plan highlights a detailed budget with an estimated total budgetary cost for the plan's implementation, a breakdown of revenue to be received from estimated funding sources, and an estimated cost range for each potential action. The findings further reveal that the provision of a plan to report implementation outcomes had the highest score (142) among all the monitoring, evaluation, reporting, and learning principles. The least considered criteria for monitoring, evaluation, reporting, and learning were the indication of a procedure for stakeholder feedback/knowledge sharing/learning (36) and a system for evaluation (44.5). These findings have also been found in previous studies [6,80], attributing the phenomenon to the lack of vigorous guiding tools, limited capacity, resources, and data to develop monitoring, evaluation, reporting, and learning frameworks, and outcome indicators/metrics [6,81]. Overall, six criteria, including trade-offs and/or conflicts, stakeholder feedback/knowledge sharing and learning, financing secured, common evaluation procedure, cost estimates of damages of climate impacts, and the availability of governance structure, had the weakest average scores among all the criteria, obtaining an average score less than 0.25. Consequently, this observation limits the tendency for urban climate planners to avoid maladaptation in climate planning and undermine cities' efforts in contributing to transparent and inclusive national and global emission reduction and adaptation targets.

4.3. *Assessing the suitability of urban CAPs*

This study evaluated the total number of urban CAPs and their level of suitability by adopting the WAI to weigh the total scores of the urban CAPs. The total WAI value ranges between 0 and 1. The level of suitability is detailed in the methodology section of this study. Table 5 shows the total urban CAPs and their level of suitability. The results indicate that most urban CAPs (59%) analyzed have a "medium" level of suitability. More than one-third of the urban CAPs are classified as having a "weak" level of suitability, with just 2% of the CAPs achieving a "strong" suitability rating, as presented in Table 5. Strikingly, none of the urban CAPs achieved a "very strong" suitability status, confirming that no urban CAP obtained a score of 1 across all the 43 criteria in the framework.

Fig. 6 depicts a map of the total urban CAPs analyzed and their level of suitability. Fig. 6 shows that of the eight urban CAPs analyzed from Africa, none of them had a "weak" suitability rating, with many of them (88% - 7 urban CAPs) achieving a "medium" suitability status. All three urban CAPs from Latin America included in the study attained a "medium" suitability score. The study also found that no urban CAP in Europe achieved a "strong" suitability status, with more than half (51% - 29 urban CAPs of 57 urban CAPs) achieving a "weak" suitability rating. This weak performance from urban CAPs in Europe is likely to result in inefficiencies in contributing to national climate objectives within the EU region, as concluded by Ref. [71]. The rest of the continents had at least one urban CAP, obtaining either a "strong," "medium," or "weak" suitability rate.

The top and bottom ten urban CAPs were ranked according to their suitability scores. Fig. 7 displays the top ten and bottom ten cities ranked according to the suitability scores of their urban CAPs. The results show that the City of Johannesburg Climate Action Plan had the highest WAI value, attaining a value of 0.86, while the Climate and Energy Strategy for Oslo was ranked as having the lowest suitability score, as illustrated in Fig. 7.

The study found that the bottom ten urban CAPs ranked were from cities in Asia, Europe, North America, and Oceania (Fig. 7). As seen in Figs. 7 and 6 out of the 16 sampled urban CAPs from the Global South (Johannesburg, Mumbai, Nairobi, Accra, Dakar, and Cape Town) were ranked among the top 10 urban CAPs with the highest suitability scores. Supplementary Appendix 5 presents the suitability scores across the 257 sampled cities.

Since the framework's comprehensiveness involves including recent criteria and best practices for urban climate planning, the research analyzed whether the suitability of urban CAPs could be determined by the year of its adoption or publication. As indicated in the methodology section, the study only included urban CAPs adopted or published from 2015 to 2022. This analysis excluded ten urban CAPs adopted or published at different periods but are linked together as the CAP for the city in question. Fig. 8 illustrates the relationship between urban CAP suitability scores, their year of adoption or publication (8a), and the global divide (8b). Results from a Kruskal-Wallis test imply a statistically significant difference between the year of adoption or publication of urban CAPs and their suitability scores (p-value of 0.0001027), as visible in Fig. 8a. The pairwise comparison test also shows statistically significant differences in the suitability scores between plans adopted or published much earlier (2015–2017) and more recently adopted or published plans (beyond 2017).

The results further stipulate that more recently adopted or published urban CAPs (beyond 2017) tend to have higher average suitability scores as compared to urban CAPs adopted or published much earlier (2015–2017). Similar findings were discovered by Ref. [82], concluding that an association exists between resilience scores and the year of adoption of comprehensive plans from coastal communities across Maine, USA. A critical examination of Fig. 8a posits that urban CAPs adopted or published in 2022 have a higher median than those adopted or published earlier. This result suggests that current urban CAPs are more likely to be suitable than those published earlier. The results from the Mann-Whitney *U* test depict strong evidence to conclude that the suitability scores of urban CAPs from cities in the Global North and Global South are significantly different (p-value = 9.754e – 05). Overall, the results show that urban CAPs from the Global North have lower average suitability scores as compared to those from the Global South, as displayed in Fig. 8b, emphasizing that urban CAPs from cities in the Global South are more likely to be consistent with conventional urban climate action planning standards, criteria, and benchmarks than those from the Global South.

A critical content analysis of the sampled urban CAPs reveals that apart from Hong Kong, almost all the cities (about 94%) sampled from the Global South clearly indicated receiving either external technical assistance from international climate bodies (such as the C40s, ICLEI, the World Resource Institute), and UN-Habitat), climate-related research institutions and experts (such as foreign universities and climate consultancy firms), or participates in global climate programs including the C40 Deadline 2020 Programme, 100 Resilient Cities Program, and the GCoM. These partnerships, support, and expertise (mostly from the Global North) largely influenced the efforts of Global South cities in developing suitable CAPs [6]. concluded that such initiatives also provide knowledge transfer and learning opportunities among cities.

Table 5
Total urban CAPs and their level of suitability.

Level of suitability	Number of urban CAPs	% (Total)
Very strong	0	0
Strong	6	2
Medium	152	59
Weak	99	39
Very weak	0	0
Total	257	100

4.4. Limitations and suggestions for future studies

This study reveals that most urban CAPs have a medium level of suitability, with a majority of them largely addressing criteria for setting and communicating climate visions and targets. However, the scope of sampled cities for this study limits efforts to generalize its findings, although it presents a global perspective of the suitability of urban CAPs across regions, city types, and the global divide. The suitability test in this study, for instance, did not include most climate action plans from the over 12,000 member cities in the GCoM for Climate and Energy and the over 10,000 cities in the EU. This limitation is due to the lack of accessibility to city-level CAPs using the study's search strategy and resource constraints in translating texts of non-English urban CAPs into English. This suggests that, while the study's sample represents cities from the Global North and Global South, including more non-English urban CAPs (such as those from GCoM for Climate and Energy member cities) in the suitability analysis could have presented different results. This study suggests that future research on the suitability of urban CAPs using the UCAP framework should consider exploring non-English urban CAPs to enhance the robustness and extensiveness of the analysis. Again, the study suggests that urban climate planners and policymakers make urban CAPs accessible to support the comprehensiveness of research of this nature.

The analysis also focuses on urban CAPs adopted or published from 2015 to 2022. This period only gives insights into the suitability of urban CAPs after the release of the IPCC Fifth Assessment Report in 2014 and the inception of the Paris Agreement till the Conference of Parties 27 in November 2022. Future research should perform a comparative analysis between CAPs adopted or published before and after the IPCC Fifth Assessment Report (2014) release and highlight the dynamics accordingly. Further comparisons should also be made with plans adopted or published after 2022, the year of finalization of the IPCC Sixth Assessment Report. This research's analysis strictly focused on the contents of the sampled urban CAPs, which might affect data granularity, accuracy, and generalization regarding the actual climate planning efforts of cities having separate climate action planning and implementation documents. This study recommends that future primary studies on this matter should determine the existence of separate frameworks or documents, such as detailed budgets, monitoring, evaluation, reporting, and learning frameworks, and stakeholder engagement reports. Including such documents in the analysis will present fascinating evidence on the suitability of urban CAPs. The statistical analysis in this study only establishes possible relationships between the variables in question. Interesting evidence can be statistically ascertained by future research on actual causalities between, for instance, the year of adoption and publication of an urban CAP and adaptation or mitigation objectives achieved. The suitability analysis conducted in this study does not transcend to establish actual outcomes and cost-effectiveness in implementing climate actions in the long term. Studies of this nature in the future can conduct an impact assessment of suitable urban CAPs in contributing to the climate change agenda and achieving climate targets. In practice, local governments are encouraged to use this study's framework as a toolkit in developing CAPs consistent with globally acknowledged climate action planning standards, criteria, and benchmarks and to satisfy recommendations for urban climate action planning from international climate networks, including C40s and GCoM for Climate and Energy. This will increase the probability of achieving cost-effective implementation results, including urban climate targets.

5. Conclusion

As the world is projected to be highly urbanized by 2050, cities are encouraged to take urgent climate actions to mitigate and adapt to the threats of climate change. This study sought to propose an integrated and comprehensive framework grounded on recent scientific studies and climate planning benchmarks to guide the development of suitable

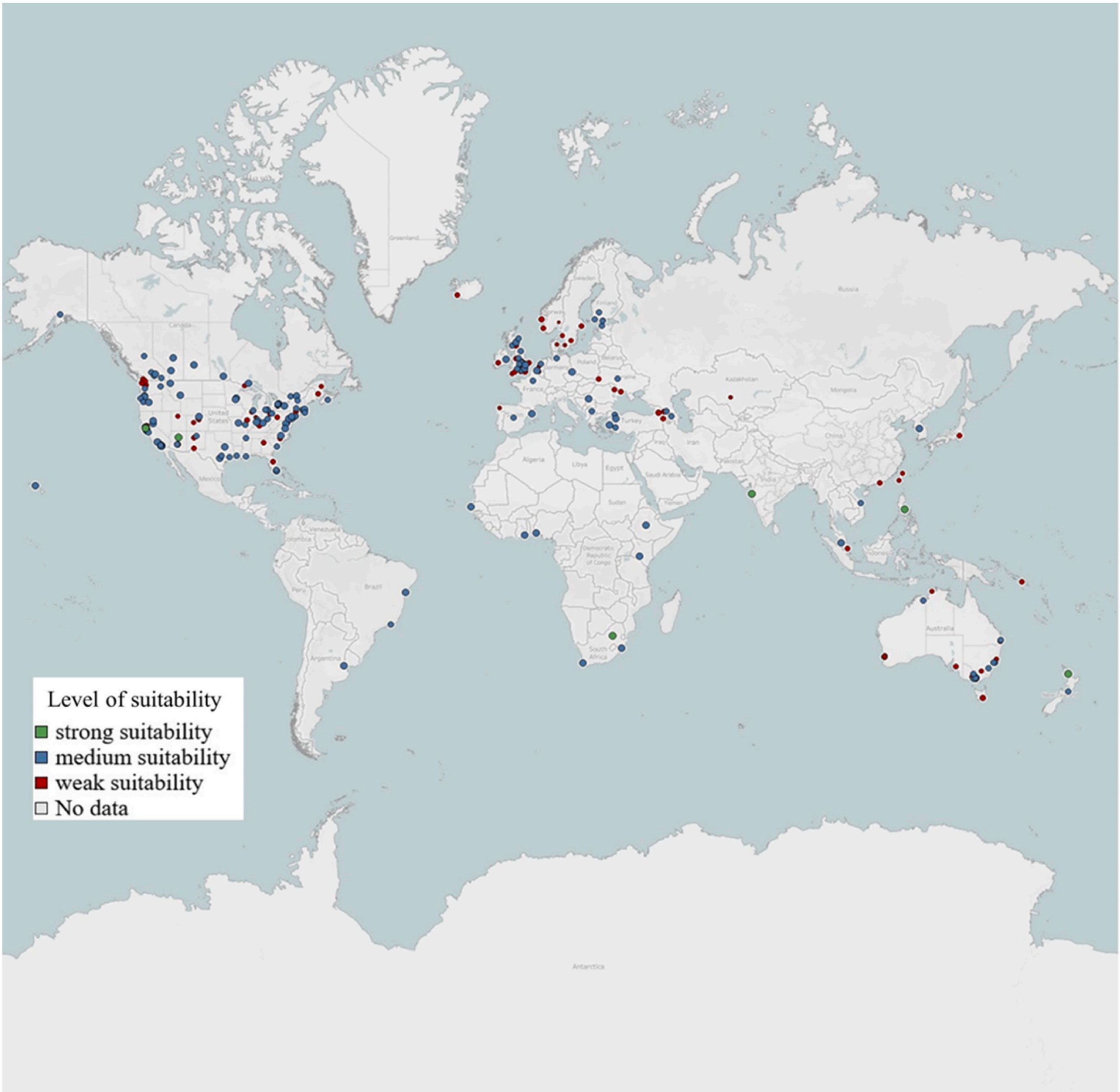


Fig. 6. Map of total urban CAPs analyzed and their level of suitability. Check the colored version for details.

urban CAPs and support the assessment of the level of suitability of urban CAPs. As a case study, the framework was used to pilot test the suitability of 257 urban CAPs adopted or published after 2014. Non-parametric tests were conducted to analyze plausible relationships between city types and total scores across three stages of climate planning. Similar statistical tests were done between years of adoption and publication, the global divide, and the suitability of urban CAPs.

The analysis highlights critical results to enhance urban climate action planning as cities face imminent climate threats. Among the three stages of climate planning, the study discovered that, as it stands, the inclusion of critical elements for financing, implementing, and monitoring climate actions is less visible in existing urban CAPs adopted or published after 2014, contrary to evidence that the majority of cities under the covenant of mayors initiative consider these elements in their energy action plans [54]. The results of the study are significant in furthering national and global discussion on promoting transparent, inclusive, and proactive urban climate planning as efforts to reduce GHG emissions, promote sustainable energy consumption, and address financing gaps in urban climate action implementation heighten. The analysis shows a significant association between city size and the extent to which criteria in the three stages of climate planning are explicitly considered. Generally, large cities tend to perform averagely better in incorporating important criteria across all three stages of climate planning than mega, medium, and small cities. The study realized that most urban CAPs from mega, medium, and small cities performed averagely lower in addressing stage three of climate planning. This study encourages that, going forward, climate education and capacity-building initiatives and programs on climate planning should strategically

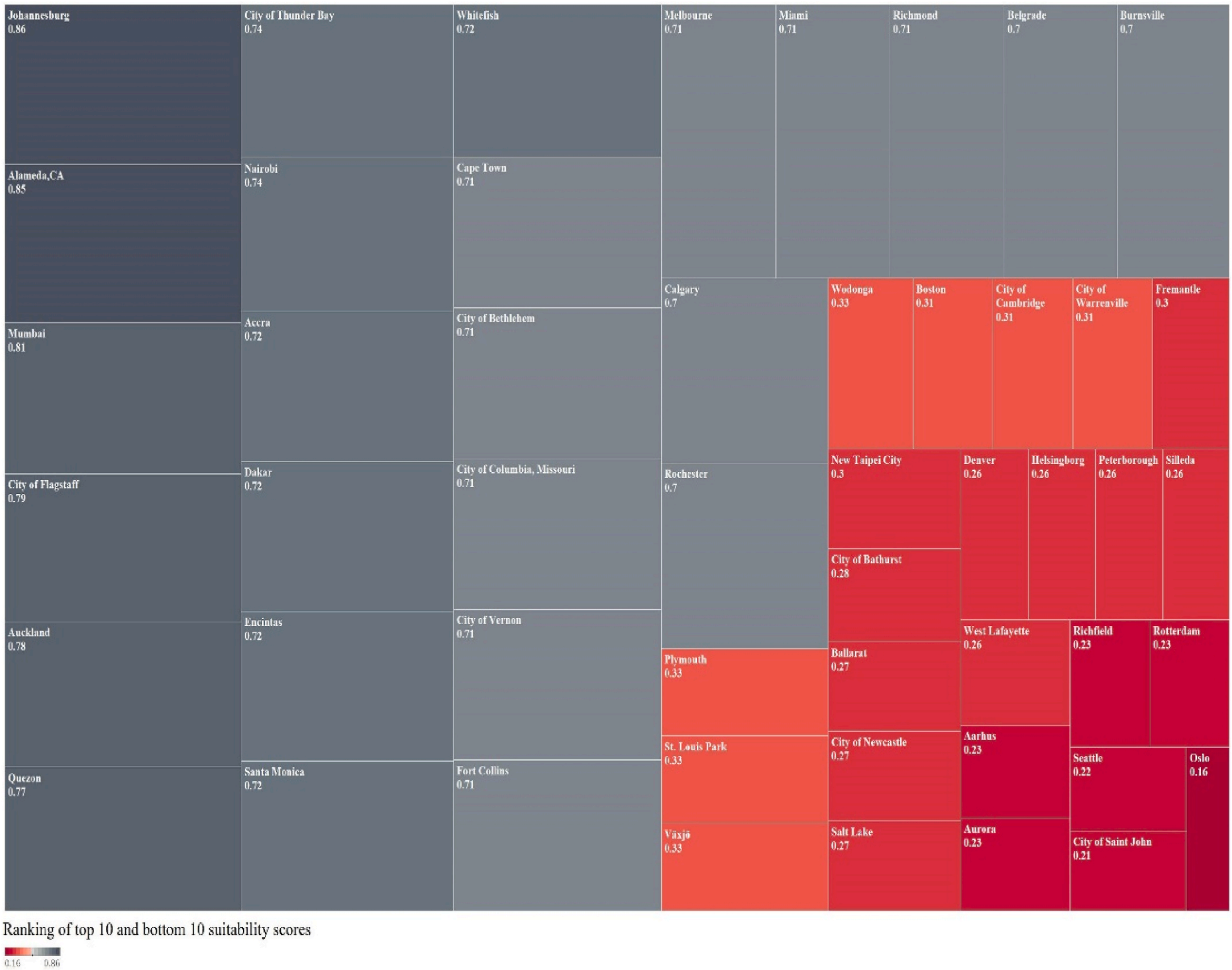


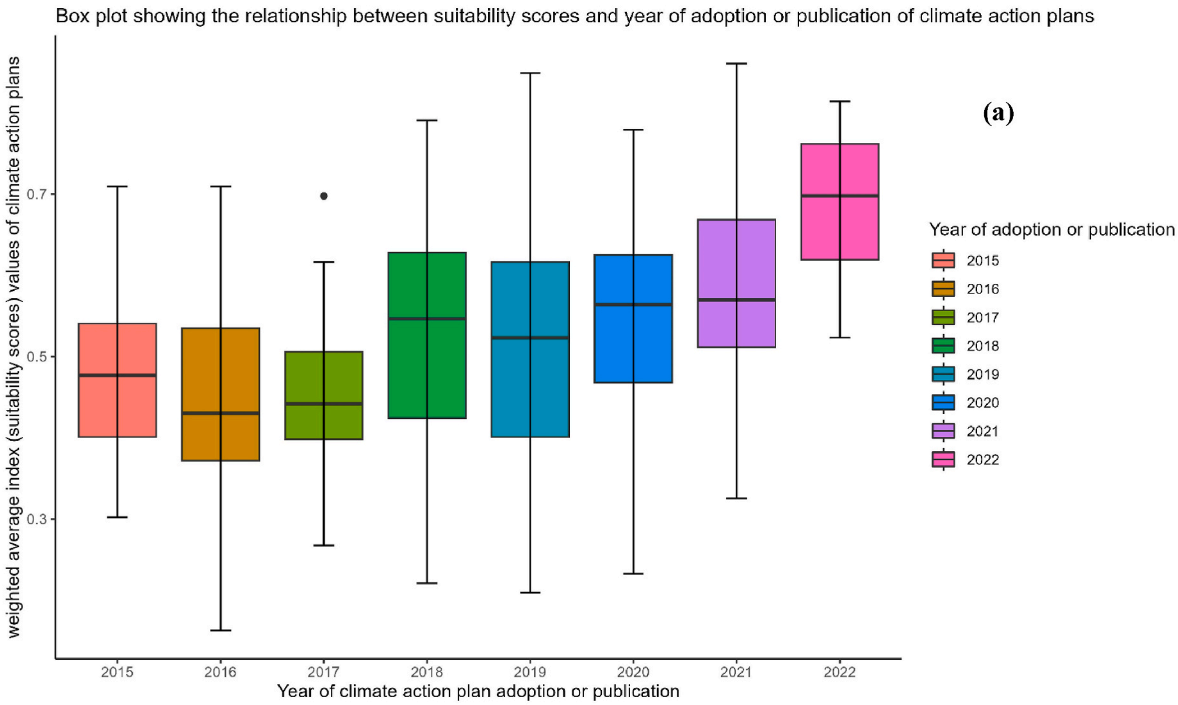
Fig. 7. A Treemap chart of the top ten and bottom ten cities according to the suitability scores of their urban CAPs.

involve more mega, medium, and large cities, especially in regions where climate education and capacity for climate action planning are inadequate. This is imperative since evidence postulates that the majority of cities in the world are either mega, medium, or small. The performance of these cities in developing suitable CAPs will contribute immensely to global GHG emission reduction, promote energy efficiency, climate resilience, air quality, and ultimately promote long-term sustainability across the globe.

The study found disparities in the explicit incorporation of individual criteria in the framework. In analyzing the ten individual criteria in stage one of climate planning, the findings denote that more emphasis is placed on indicating the GHG emissions profile and forecasts. Again, risk analysis in the sampled urban CAPs largely concentrates on climate hazard and vulnerability profiling, with limited emphasis on exposure profiling. Evidence on the economic cost of damages of climate impacts and uncertainties of climate impacts were extremely not considered in the sampled urban CAPs. In practice, this evidence threatens decision-making for selecting appropriate climate actions and detecting how gross the climate situation can be if it is not addressed. This study suggests that urgent importance should be given to developing more enhanced models and tools that can simulate and estimate the economic cost of climate impacts and the uncertainties of climate impacts on sectors of cities.

At the level of target setting, more prominence was given to setting GHG emission reduction targets (249 of possible 257) over adaption objectives (212 of possible 257). Yet, the degree of importance placed on deep decarbonization pledges was inconsistent with overall GHG mitigation targets. General sectoral targets in the sampled urban CAPs are also not SMART. Perhaps, cities need to invest in baseline research to ascertain essential scientific data for developing SMART sectoral targets. Again, it is important for urban climate planners to recognize systems for researchers and climate scientists to support the provision of scientific data in developing SMART climate targets. The collection of activity data and per-sector GHG emissions data is essential to develop SMART mitigation-related sectoral targets and to efficiently track efforts in mitigation-related sectors (mainly in the energy, transport, industry, waste, and agriculture, forestry, and land use (AFOLU) sectors). Cities should also exhibit efforts to communicate, educate, and create awareness of their climate visions and actions for inclusive, transparent, and proactive urban climate planning. However, collaborative efforts between national governments, the private sector, and civil society are needed to maximize inclusiveness, transparency, and proactiveness in urban climate planning.

The analysis of individual criteria addressed by cities reveals concerning evidence for financing, implementation, monitoring, evaluation, reporting, and learning. The results show that a significant percentage of urban CAPs failed to explicitly disclose funding already secured for prioritized climate actions. Most cities also prioritize



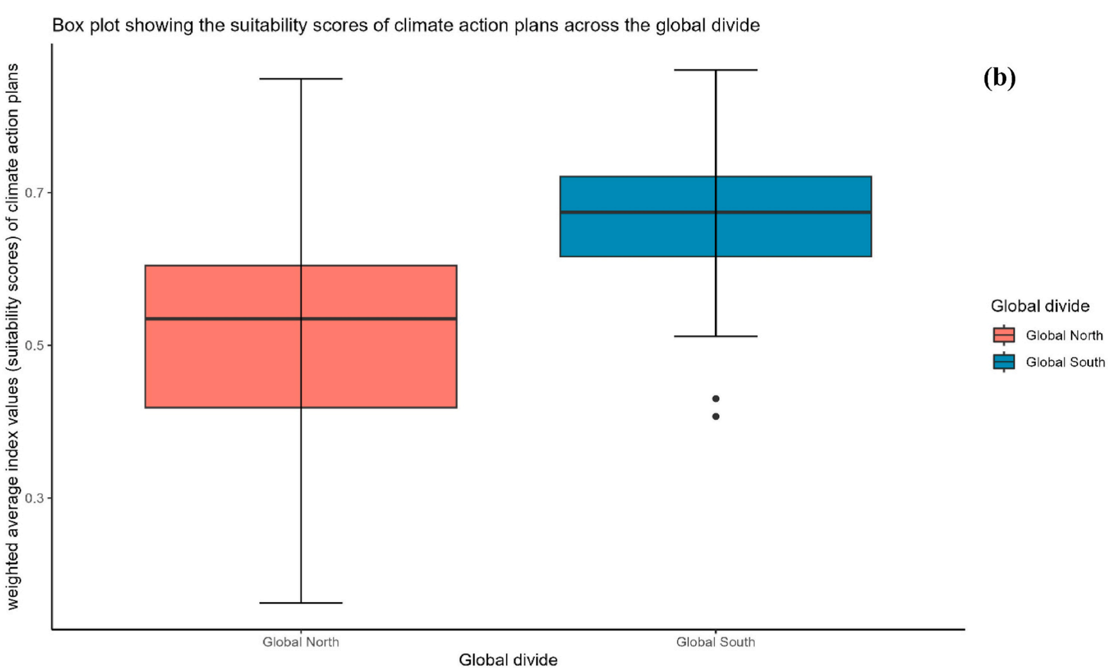


Fig. 8. Relationships between suitability scores and **(a)** year of adoption or publication of urban CAP (from a Kruskal-Wallis test and Dunn's post hoc test; Chi-Square = 29.815; df = 7) and **(b)** the Global divide (from a Mann-Whitney *U* test; W = 886; P-Value = 9.754e − 05).

indicating the monetary costs of their climate actions over the monetary benefits. Local governments should make an effort to adopt scientific data and collaborate with partners to assess the possible costs and benefits of their climate actions. Cities are also giving prominence to equity, the consideration of extra sustainability benefits, and the consideration of future technology/innovation advancement, with all of them achieving more than half of the possible total scores. The consideration of current and future pandemics (such as COVID-19) and measures for green economic recovery in climate planning did not receive much prominence, probably because it's a recent phenomenon. The sampled cities also plan to achieve multiple benefits (co-benefits and/or synergies) from integrating climate mitigation and adaptation actions. Yet, few of them discussed possible trade-offs and conflicts that may occur from prioritized climate actions. Two critical elements for CAP implementation – governance structure/framework and resource (human and budgets) estimations were largely not given explicit importance by the sampled urban CAPs, although they are prioritized elements in existing frameworks such as the EUCoM's Guidebook on developing SECAPs.

While existing frameworks, including the GCoM Common Reporting Framework and the EUCoM Guidebook for developing SECAP, recommend cities inculcate measures for financing, budgeting, and monitoring, evaluation, reporting, and learning, this study shows that when cities tend to indicate budgets in their urban CAPs, most do not present a detailed breakdown of their budgets. This study also found relatively higher scores in sampled cities' intentions to report on the outcomes of implementing their climate actions. Plans to receive feedback and a procedure for evaluating implementation outcomes were extremely not emphasized in the sampled urban CAPs. Contrary evidence to this finding is revealed in Palermo et al. [55] and Rivas et al. [54] for cities that are signatories to the GCoM; however, to expand the geographical scope in suitable climate action planning, this study strongly advocates for capacity-building programs and awareness by international climate networks and climate research institutions to focus on how other cities can inculcate detailed strategies for financing, implementing, monitoring, evaluating, and reporting CAP progress and outcomes. According to the analysis of this study, the approach has greatly influenced plan development in cities from the Global South.

None of the urban CAPs analyzed met the "very strong" or "very weak" suitability criteria. More than half of the sampled urban CAPs obtained a medium level of suitability, with almost 40% of them attaining a weak suitability status. Only 2% of the sampled urban CAPs were ranked as having a strong level of suitability. Encouragingly, urban CAPs from Africa and Latin America performed relatively well in the suitability analysis (the majority achieving medium suitability and none obtaining a weak suitability status). The study revealed that urban CAPs sampled from the Global South have a higher average suitability than those from the Global North, with about 51% of urban CAPs from Europe achieving a weak suitability status. This study does not suggest that suitable plans will automatically return cost-effective and high implementation performance. Future studies are encouraged to statistically evaluate the impacts of suitable CAPs from cities in the Global North and Global South on climate adaptation and mitigation, particularly in GHG emission reduction, sustainable energy consumption, green jobs, and urban climate resilience. This future analysis will provide more insights to confirm or disprove this study's hypothesis of suitable urban CAPs as cost-effective and relevant to achieving the climate objectives of the city. However, the research presumes that if more climate funding for research and development (R&D), partnerships, knowledge sharing, and implementation is concentrated on cities from the Global South, there is a high possibility of achieving positive climate targets from these areas. Currently, the majority of funding for energy and climate change R&D is mainly concentrated in the Global North, with very low amounts concentrated in the Global South, particularly Latin America and Africa [83]. Finally, the study found significant differences between urban CAPs and their year of adoption or publication, with more recent urban CAPs (CAPs adopted or published from 2018 to 2022) having higher average suitability scores than earlier urban CAPs (CAPs adopted or published from 2015 to 2017). National governments are recommended to ensure better coordination and collaborations among different levels of local authorities, civil society, and the private sector in local climate action planning. This will enable local governments to leverage expertise and resources from diverse areas to develop suitable action plans. National climate policies should adopt regulatory and legal frameworks that mandate local climate action planning to inculcate criteria necessary for developing suitable CAPs. The relationship between legal and regulatory frameworks enshrined in national climate policies and the development of suitable urban CAPs should be further studied through in-depth critical content analysis, key informant interviews, and surveys.

CRediT author statement

PRINCE DACOSTA ABOAGYE: Methodology, Data curation, Visualization, Writing- Original draft preparation, Writing- Review & Editing Ayyoob Sharifi: Conceptualization, Methodology, Writing- Review &; Editing.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

Data availability

Data will be made available on request.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.rser.2023.113886.

References

[1] United Nations Department of Economic and Social Affairs. World Urbanization Prospects. The 2018 revision (ST/ESA/SER.A/420). New York. 2019.
[2] Pizzorni M, Caldarice O, Tollin N. A methodological framework to assess the urban content in climate change policies. Valori e Valutazioni 2021;29.
[3] Gu D. Population Division Exposure and vulnerability to natural disasters for world's cities*. 2019.
[4] Christiana F, Corinne Le Q, Anand M, Oliver B, Gail W, Glen P, et al. Emissions are still rising: ramp up the cuts. Nature 2018;564:27–30.
[5] United Nations Environment Programme. Emissions gap report 2022. 2022.
[6] Olazabal M, Ruiz De Gopegui M. Adaptation planning in large cities is unlikely to be effective. Landsc Urban Plann 2021;206.
[7] Shuaib Lwasa KCS, Bai Xuemei, Blanco Hilda, Gurney Kevin R, Şiir Kılkış, Lucon Oswaldo, Jin Murakami, Pan Jiahua, Sharifi Ayyoob, Yamagata Yoshiki. Urban Systems and other settlements. IPCC, 2022: climate change 2022: mitigation of climate change contribution of working Group III to the sixth assessment report of the Intergovernmental Panel on climate change. Cambridge, UK and New York, NY, USA: Cambridge University Press; 2022.
[8] Yin L, Sharifi A, Liqiao H, Jinyu C. Urban carbon accounting: an overview. Urban Clim 2022;44:101195.
[9] Watts M. Commentary: cities spearhead climate action. Nature climate change. Nature Publishing Group; 2017. p. 537–8.
[10] Reckien D, Salvia M, Heidrich O, Church JM, Pietrapertosa F, De Gregorio-Hurtado S, et al. How are cities planning to respond to climate change? Assessment of local climate plans from 885 cities in the EU-28. J Clean Prod 2018;191:207–19.
[11] Grafakos S, Trigg K, Landauer M, Chelleri L, Dhakal S. Analytical framework to evaluate the level of integration of climate adaptation and mitigation in cities. Climatic Change 2019;154:87–106.
[12] United Cities and Local Governments. climate_summit_final_declaration. 2015. https://wwwuclgorg/sites/default/files/climate_summit_final_declarationpdf;. [Accessed 19 December 2022].
[13] United Nation. Climate Action Summit delivers major step-up in national ambition, private sector initiatives on pathway to key 2020 deadline. UN Press; 2019. https://pressunorg/en/2019/envdev1998dochtm. [Accessed 19 December 2022].
[14] Salvia M, Reckien D, Pietrapertosa F, Eckersley P, Spyridaki NA, Krook-Riekkola A, et al. Will climate mitigation ambitions lead to carbon neutrality? An analysis of the local-level plans of 327 cities in the EU. Renew Sustain Energy Rev 2021;135.
[15] Hsu A, Tan J, Ng YM, Toh W, Vanda R, Goyal N. Performance determinants show European cities are delivering on climate mitigation. Nat Clim Change 2020;10:1015–22.
[16] IPCC. Summary for policymakers. Climate change 2014: mitigation of climate change. Contribution of working Group III to the fifth assessment report of the Intergovernmental Panel on climate change. Geneva, Switzerland. 2014. p. 151.
[17] IPCC. Summary for policymakers. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral Aspects. Contribution of working Group II to the fifth assessment report of the Intergovernmental Panel on climate change. Cambridge University Press, Cambridge and New York: Alistair Woodward; 2014. p. 1–32. Josef Settele.
[18] Sharifi A. *Trade-offs and conflicts between urban climate change mitigation and adaptation measures: A literature review.* J Clean Prod 2020;276:122813.
[19] Damsø T, Kjær T, Christensen TB. Implementation of local climate action plans: Copenhagen–Towards a carbon-neutral capital. J Clean Prod 2017;167:406–15.
[20] Tiepolo M. Relevance and quality of climate planning for large and medium-sized cities of the tropics. Green energy and technology. Springer Verlag; 2017. p. 199–226.
[21] Azevedo I, Leal VMS. Methodologies for the evaluation of local climate change mitigation actions: a review. Renew Sustain Energy Rev 2017:681–90. Elsevier Ltd.
[22] Wei T, Wu J, Chen S. Keeping track of greenhouse gas emission reduction progress and targets in 167 cities worldwide. Front Sustain Cities 2021;3.
[23] Grafakos S, Viero G, Reckien D, Trigg K, Viguie V, Sudmant A, et al. Integration of mitigation and adaptation in urban climate change action plans in Europe: a systematic assessment. Renew Sustain Energy Rev 2020;121.
[24] Chang M, Thellufsen JZ, Zakeri B, Pickering B, Pfenninger S, Lund H, et al. Trends in tools and approaches for modelling the energy transition. Appl Energy 2021;290.

[25] Bertoldi PD, BC S, M R. PDR. Guidebook. How to develop a sustainable energy action plan (SEAP). Luxembourg (Luxembourg): Publication Office of the European Union; 2010.
[26] Andreanidou K, Bertoldi P, Dallemand J, Follador M, Glancy R, Hernandez Gonzalez Y, et al. Guidebook 'How to develop a sustainable energy and climate action plan (SECAP)'. Luxembourg: Publications Office of the European Union; 2018.
[27] Global Covenant of Mayors for Climate and Energy. Global covenant of mayors common reporting framework. 2018.
[28] Mimura N, Pulwarty RS, Minh Duc D, Elshinnawy I, Hiza Redsteer M, Huang H-Q, et al. Adaptation planning and implementation. Climate change 2014: impacts, adaptation, and vulnerability. Part A: global and sectoral Aspects. Contribution of working Group II to the fifth assessment report of the Intergovernmental Panel on climate change. Cambridge, United Kingdom and New York, NY, USA: Cambridge University Press; 2014.
[29] UN-Habitat. Guiding principles for climate city planning action guiding principles for city climate action planning. 2015. https://unhabitatorg/guiding-principles-for-city-climate-action-planning. [Accessed 9 October 2022].
[30] ICLEI. ICLEI's Climate Neutrality Framework Accelerating integrated climate action for sustainable urban development ICLEI's Climate Neutrality Framework. 2020. https://e-libicleiorg/publications/ICLEIs_Climate_Neutrality_Frameworkpdf. 9th October 2022.
[31] C40s. Climate action planning framework. 2020.
[32] Sheehan MC, Freire M, Martinez GS. Piloting a city health adaptation typology with data from climate-engaged cities: toward identification of an urban health adaptation gap. Environ Res 2021;196.
[33] Tyler S, Moench M. A framework for urban climate resilience. Clim Dev 2012: 311–26.
[34] Swanson K. Equity in urban climate change adaptation planning: a review of research. Urban Planning: Cogitatio Press; 2021. p. 287–97.
[35] IPCC. Summary for policymakers. Climate change 2022: mitigation of climate change. Contribution of working Group III to the sixth assessment report of the Intergovernmental Panel on climate change.. 2022.
[36] Tiepolo M. Relevance and quality of climate planning for large and medium-sized cities of the tropics. Renewing local planning to face climate change in the tropics. 2017. p. 199–226.
[37] Salvia M, Reckien D, Pietrapertosa F, Eckersley P, Spyridaki N-A, Krook-Riekkola A, et al. Will climate mitigation ambitions lead to carbon neutrality? An analysis of the local-level plans of 327 cities in the EU. Renew Sustain Energy Rev 2021;135.
[38] Azevedo I, Leal V. A new model for ex-post quantification of the effects of local actions for climate change mitigation. Renew Sustain Energy Rev 2021;143.
[39] Victor, D.G. and M. Muro. *Cities are pledging to confront climate change, but are their actions working? Retrieved from: https://www.brookings.edu/articles/cities-are-pledging-to-confront-climate-change-but-are-their-actions-working/ on May 15, 2023.* 2020.
[40] Rosenzweig C, Solecki W, Hammer AS, Mehrotra S. Cities lead the way in climate-change action. Nature 2010;467:909–11.
[41] C40s. C40 annual report 2021. 2021.
[42] CDP. 20th Anniversary - CDP. https://wwwcdpnet/en/info/about-us/20th-anniversary#34e2d1989a1dbf75cd631596133ee5ee2021.
[43] Rivas S, Urraca R, Bertoldi P, Thiel C. Towards the EU Green Deal: local key factors to achieve ambitious 2030 climate targets. J Clean Prod 2021;320.
[44] Kona A, Bertoldi P, Monforti-Ferrario F, Rivas S, Dallemand JF. Covenant of mayors signatories leading the way towards 1.5 degree global warming pathway. Sustain Cities Soc 2018;41:568–75.
[45] Hoornweg D, Sugar L, Trejos Gomez CL. Cities and greenhouse gas emissions: moving forward. Classics Urbanisation 2020;5:43–62.
[46] Otto A, Kern K, Haupt W, Eckersley P, Thieken AH. Ranking local climate policy: assessing the mitigation and adaptation activities of 104 German cities. Clim Change 2021;167.
[47] Fiack D, Cumberbatch J, Sutherland M, Zerphey N. Sustainable adaptation: social equity and local climate adaptation planning in U.S. cities. Cities 2021;115.
[48] Dulal HB. Cities in Asia: how are they adapting to climate change? J Environ Stud Sci 2019;9:13–24.
[49] Guyadeen D, Thistlethwaite J, Henstra D. Evaluating the quality of municipal climate change plans in Canada. Clim Change 2019;152:121–43.
[50] Singh C, Madhavan M, Arvind J, Bazaz A. Climate change adaptation in Indian cities: a review of existing actions and spaces for triple wins. Urban Clim 2021;36.
[51] Donatti CI, Harvey CA, Hole D, Panfil SN, Schurman H. Indicators to measure the climate change adaptation outcomes of ecosystem-based adaptation. Climatic Change 2020;158:413–33.
[52] Sharifi A. Co-benefits and synergies between urban climate change mitigation and adaptation measures: a literature review. Science of the Total Environment: Elsevier B.V.; 2021.
[53] UN-Habitat. Guiding principles for city climate action planning. Nairobi: UN-Habitat; 2015.
[54] Rivas S, Urraca R, Palermo V, Bertoldi P. Covenant of Mayors 2020: drivers and barriers for monitoring climate action plans. J Clean Prod 2022;332:130029.
[55] Palermo V, Bertoldi P, Apostolou M, Kona A, Rivas S. Assessment of climate change mitigation policies in 315 cities in the Covenant of Mayors initiative. Sustain Cities Soc 2020;60:102258.
[56] Restemeyer B, Woltjer J, van den Brink M. A strategy-based framework for assessing the flood resilience of cities – a Hamburg case study. Plann Theor Pract 2015;16:45–62.
[57] Balaban O. Developing an indicator-based approach to evaluate the effectiveness of urban regeneration for climate change mitigation and adaptation UNU-IAS sustainable urban futures view project. 2011.
[58] Lindgren B-M, Lundman B, Graneheim UH. Abstraction and interpretation during the qualitative content analysis process. Int J Nurs Stud 2020;108:103632.
[59] Khirfan L, Peck M, Mohtat N. Systematic content analysis: a combined method to analyze the literature on the daylighting (de-culverting) of urban streams. MethodsX 2020;7:100984.
[60] European Commission. European missions info kit for cities interested in participating in the call for expression of interest (EOI). 2021.
[61] World Resources Institute. City climate action planning. 2019. p. 1–26. Learning Guide.
[62] Habitat UN. What is a City?. 2020. p. 2–4. https://unhabitatorg/sites/default/files/2020/06/city_definition_what_is_a_citypdf;. [Accessed 3 December 2022].
[63] Lamb WF, Creutzig F, Callaghan MW, Minx JC. Learning about urban climate solutions from case studies. Nature climate change. Nature Publishing Group; 2019. p. 279–87.
[64] Aboagye PD, Sharifi A. Post-fifth assessment report urban climate planning: lessons from 278 urban climate action plans released from 2015 to 2022. Urban Clim 2023;49:101550.
[65] United Nations Department of Economic and Social Affairs. The World's Cities in 2018. 2018.
[66] Kowalski AM. Global South-Global North differences. 2020. p. 1–12.
[67] Williams PA, Crespo O, Abu M. Adapting to changing climate through improving adaptive capacity at the local level – the case of smallholder horticultural producers in Ghana. Clim Risk Manag 2019;23:124–35.
[68] Ndamani F, Watanabe T. Farmers' perceptions about adaptation practices to climate change and barriers to adaptation: a micro-level study in Ghana. Water (Switzerland) 2015;7:4593–604.
[69] Chandraaroy B, Hossain ME. Perception of climate change and association between adaptation decision and household characteristics of smallholder farmers in Rajshahi District. Soc Sci J, Fac Soc Sci 2020:279–92.
[70] Gunawan E, Kuwornu JKM, Datta A, Nguyen LT. Farmers' perceptions of the warehouse receipt system in Indonesia. Sustainability (Switzerland) 2019;11.
[71] Reckien D, Flacke J, Dawson RJ, Heidrich O, Olazabal M, Foley A, et al. Climate change response in Europe: what's the reality? Analysis of adaptation and mitigation plans from 200 urban areas in 11 countries. Climatic change. Kluwer Academic Publishers; 2014. p. 331–40.
[72] Leal Filho W, Stojanov R, Wolf F, Matandirotya NR, Ploberger C, Ayal DY, et al. Assessing uncertainties in climate change adaptation and land management. Land 2022;11:2226.
[73] Thupalli R, Deen TA. An investment strategy for reducing disaster risks and coastal pollution using nature based solutions. 2018. p. 141–70.
[74] Allam Z, Sharifi A, Giurco D, Sharpe SA. Green new deals could be the answer to COP26's deep decarbonisation needs. Sustainable Horiz 2022;1:100006.
[75] Green EJ, Buchanan GM, Butchart SHM, Chandler GM, Burgess ND, Hill SLL, et al. Relating characteristics of global biodiversity targets to reported progress. Conserv Biol 2019;33:1360–9.
[76] Markanday A, Galarraga I, Markandya A. A critical review of cost-benefit analysis for climate change adaptation in cities. Climate change economics. World Scientific Publishing Co. Pte Ltd; 2019.
[77] Sharifi A, Pathak M, Joshi C, He B-J. A systematic review of the health co-benefits of urban climate change adaptation. Sust Cities Soc 2021;74:103190.
[78] Sharifi A. In: Lackner M, Sajjadi B, Chen W-Y, editors. Sustainability and resilience Co-benefits and trade-offs of urban climate change adaptation and mitigation measures. Handbook of climate change mitigation and adaptation. Cham: Springer International Publishing; 2022. p. 1369–403.
[79] UN-Habitat. World cities report 2022. 2022.
[80] Scott H, Moloney S. Completing the climate change adaptation planning cycle: monitoring and evaluation by local government in Australia. J Environ Plann Manag 2022;65:650–74.
[81] Ebi KL, Boyer C, Bowen KJ, Frumkin H, Hess J. Monitoring and evaluation indicators for climate change-related health impacts, risks, adaptation, and resilience. Int J Environ Res Publ Health 2018;15.
[82] Cucuzza M, Stoll JS, Leslie HM. Comprehensive plans as tools for enhancing coastal community resilience. J Environ Plann Manag 2020;63:2022–41.
[83] AbdulRafiu A, Sovacool BK, Daniels C. The dynamics of global public research funding on climate change, energy, transport, and industrial decarbonisation. Renew Sustain Energy Rev 2022;162.