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Unveiling patterns in the quality and consistency of climate adaptation plans of the Global Covenant of Mayors

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Cities and urban areas are persistently praised for addressing climate impacts and risks, but metrics are lacking to check how cities fare on adaptation progress. This study introduces ADAQA-GCoM, a new tool designed to assess the quality of urban climate adaptation plans submitted to the Global Covenant of Mayors (GCoM). Applying ADAQA-GCoM to 2205 plans of the GCoM's MyCovenant dataset reveals a substantial variation in quality, though consistent patterns emerge across components and regions. Cities generally perform well in terms of their Fact Base, Measures, Implementation, and Participation, but score lower in Goals, Monitoring and Evaluation (M&E), and Consistency. Weak goal-setting and M&E indicate persistent challenges in defining measurable objectives and tracking adaptation progress. While participation is a notable strength of the GCoM framework, its implementation remains inconsistent, particularly regarding the inclusion of vulnerable groups. High-scoring plans are rare, and plan quality shows no significant association with city size or national context, suggesting that GCoM's standardized support helps bridge capacity gaps. Over time, scores for Goals, Measures, Implementation, and Participation have improved, while Fact Base and M&E have declined, likely due to shifting priorities and resources. The study demonstrates the usefulness of ADAQA-GCoM as a diagnostic and comparative tool towards more coherent, transparent, and effective urban climate adaptation planning worldwide.

Cities and urban areas have assumed a key role in addressing the impacts and risks caused by climate change[1]. However, in order to promote and implement development pathways that can deliver climate adaptation, cities need to identify *metrics for assessing adaptation options in the context of sustainable development*, as highlighted by the outline of the IPCC Special Report on Climate Change and Cities and recognized by the UAE Framework for Global Climate Resilience adopted at COP28[2]. Designing appropriate indicators in support of sustainable development and adjusted to urban contexts enables policymakers and practitioners to review overall progress in achieving global adaptation targets.

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In this regard, evaluating the effectiveness of urban climate plans has become a valuable approach to understanding and improving the way cities are planning for and advancing toward their adaptation goals. Recent developments in assessing the quality of urban climate plans represent significant progress. In particular, these studies are based on assessments of the quality of plans, which assume that good planning increases the likelihood of implementation[3]. The quality of an adaptation plan can be defined as "*the strengths of plans assumed to lead to effective implementation and reduced tradeoffs with other societal goals*"[4] [pag.2]. The central task is therefore to agree on an evaluation framework or set of indicators that best captures how planning can support implementation[4] and aligns with other societal goals, such as justice and fairness.

However, researchers face challenges when trying to operationalize these definitions. For example, it is often difficult to determine which actions 'count' as adaptation. Studies need to overcome this 'dependent variable problem' to determine how much progress is being made[5]. Additionally, adaptation is essentially location-specific: each city needs to tailor its strategy to local and regional conditions, as well as to constantly changing economic, political, geopolitical, and health conditions[6]. Moreover, adaptation must align with other local policy goals, such as the need to deliver consistent emission reductions[7], and/or balance goals of social equity and environmental justice[8–10].

Despite these challenges, adaptation planning support tools are becoming increasingly popular to support practitioners and policy-makers to take decisions. Some tools rely on academic studies that document adaptation outcomes, such as the Global Adaptation Mapping Initiative (GAMI)[11], while others focus on tools and data that help provide inputs into the planning process, such as the Climate Adaptation Knowledge Exchange (CAKE)[12] and the weADAPT platform[13]. Other examples draw on the Pathways2Resilience climate toolbox[14] and the European Union (EU) Mission on Adaptation to Climate Change database[15]. The latter provides local and regional authorities with access to decision-making tools for adaptation with reference to the 6-step policy process defined by the Regional Adaptation Tool (RAST)[16]: 1) Preparing the ground for adaptation; 2) Assessing climate risks and vulnerabilities; 3) Identifying adaptation options; 4) Assessing and selecting adaptation options; 5) Implementing adaptation policies and actions; and 6) Monitoring, evaluation and learning.

Alongside the growing interest from urban planning professionals and policy-makers in these tools, researchers have begun developing frameworks to assess the quality of urban adaptation planning. One notable contribution is the ADAptation Plan Quality Assessment (ADAQA) framework developed by Reckien et al.[4] as part of the Euro-LCP Initiative). This study tracked and evaluated the quality of 167 urban adaptation plans from a representative sample of 327 large and medium-sized cities across the EU-27 + UK. The ADAQA is available as the open-access Climate Change Adaptation Scoring Tool[17] and has been endorsed by the EU Adaptation Mission, which included it in its Mission's Tools database[18] on adaptation as "a systematic and simple framework for assessing the quality of an adaptation plan, with particular reference to the local/municipal level". The ADAQA tool uses the 6-step planning and policy cycle as a rationalistic model to compare adaptation planning processes across cities[19]. It is therefore in line with international guidelines, such as the RAST[16], and networks that support adaptation planning and implementation efforts. Some have argued that the adaptation planning and policy cycle is (too) simplistic, idealistic and sequential[19], and suggested that it insufficiently captures the contextual nature of adaptation and its local determinants[20,21]. Whilst this critique is valid, it is nonetheless useful to view the 'cycle' as a heuristic to illustrate the dynamic relationship between planning and implementation[22,23].This perspective is also supported by international city networks that promote climate policies within the framework of the Paris Agreement.

In this context, these networks can be understood as key facilitators of the planning–implementation interface, helping cities translate adaptation goals into action. They assist municipalities in designing climate policies and in sharing knowledge and best practices[24].

Among these networks, the Global Covenant of Mayors (GCoM) stands out for its broad geographic coverage and large number of signatories. Unlike other international networks, such as C40 (C40 Cities Climate Leadership Group) or ICLEI (Local Governments for Sustainability), which tend to focus on major metropolitan areas and regional governments with strong administrative and technical capacity, the GCoM primarily includes small and medium-sized cities. Moreover, it is the only initiative that requires signatories to develop a formal climate plan and monitor implementation progress. Having started in 2008 as the well-known Covenant of Mayors (CoM) initiative that supported cities to develop voluntary climate plans and implement policies in line with European Union (EU) 20-20-20 targets[25], the GCoM now incorporates members from outside of the EU. Initially focused on mitigation, GCoM signatory cities now commit to submitting an integrated plan, the Climate Action Plan (CAP), which contains measures and actions to achieve the city's goals in three GCoM pillars: mitigation, adaptation, and energy poverty reduction. The three pillars are integrated when planned interventions contribute to two or more of them, for example energy savings or hazard specification, which contribute to both mitigation and adaptation. This mechanism allows for varying levels of integration, depending on local priorities and contexts. GCoM signatories can upload contents of their CAPs to the online repositories MyCovenant and/or the CDP-ICLEI Track[26]. Currently, MyCovenant contains documentation from over 90% of all signatories[27].

The GCoM undertakes basic assessments of the quality of submitted CAPs. For example, plans are checked with regard to the completeness of data, the quantification of objectives, the compliance of timeframes, other internal coherence issues, and the monitoring of progress[28]. To develop a more sophisticated approach to evaluating adaptation plan quality, the ADAQA developers and the Joint Research Centre (JRC) in this study have further developed the ADAQA tool to apply to the GCoM context.

In this study we present the enhanced ADAQA-GCoM plan quality tool in order to assess the adaptation plans that signatories submitted through the GCoM platform. As such, it addresses the lack of research into evaluating the comprehensiveness and consistency of urban adaptation plans developed under the GCoM, and reports on the spatial distribution of plan quality across GCoM signatories worldwide. We argue that the tool will contribute to improving the adaptation components within the GCoM plans, and ultimately to the implementation of more effective adaptation measures.

To achieve this, we adapted the ADAQA tool[4] (covering the six components of the adaptation policy and planning framework: Fact Base, Adaptation Goals, Adaptation measures, Implementation, Monitoring and Evaluations, and Participation; plus 5 forms of consistency) to the context of the GCoM reporting formats. The resulting customized tool, the ADAQA-GCoM (ADAptation plan Quality Assessment tool for the Global Covenant of Mayors), focuses on the same six components of the ADAQA tool[29] and four internal consistency checks between the different parts of the plan (Fig. 1). In particular, the internal consistency checks assess whether the following elements of the plans are coherent and reinforce each other: (i) identified hazards and planned goals, (ii) identified vulnerable sectors and planned actions, (iii) identified vulnerable population groups and planned measures for vulnerable population groups, and (iv) identified hazards and planned actions (for more details see Supplementary Information 1).

We apply the ADAQA-GCoM tool to the 2205 CAPs of the GCoM submitted between 2007 and 2024, as reported in the fifth release of the GoM's MyCovenant dataset[30]. This includes the Adaptation Pillar and are referred to here as Adaptation-Climate Action Plans (A-CAP). Notably, the temporal coverage of the dataset extends from 2007 (with only Paris A-CAP) to 3 January 2024 (with no plans for 2024). In total, these plans relate to 2170 cities, as 35 cities submitted an update of an existing plan (for more details, see Supplementary Information 4). The sample includes cities from 24 out of the 27 EU countries - as of 31 January 2020 - (hereafter referred to as the EU-27), and from 11 additional countries across different world regions (Armenia, Azerbaijan, Bosnia and Herzegovina, Mexico, Norway, the Republic of Moldova, Serbia, Switzerland, Turkey, Ukraine and the

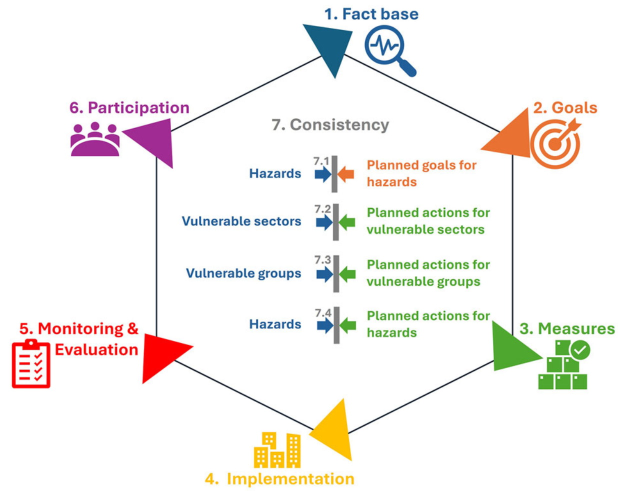

Fig. 1 | Overview of the six components and the four forms of consistency in the ADAQA-GCoM methodological approach. Consistency checks the alignment between Fact base indicators (in blue) and Goals (in orange), and between Fact base indicators and Measures (in green). Participation is a cross-cutting aspect that should be done throughout the adaptation planning process[29]. However, we mainly check for participation during plan development, which is often a dedicated, formalized process with clear start and end dates. For reasons of clarity, we keep participation as a component of the adaptation planning and policy cycle.

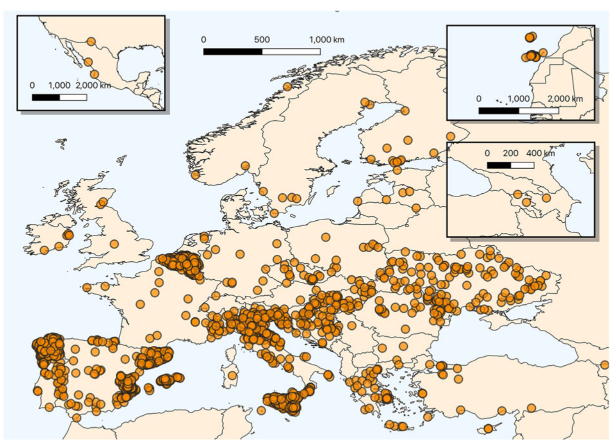

Fig. 2 | Map of all the 2170 cities considered in the dataset. The left box shows three cities in Mexico (Bahía de Banderas, Culiacán, Ciudad Juárez), the top right box shows the cities in the Canary Islands and Madeira, the bottom right box shows the two cities in Armenia (Gavar, Tashir) and the one in Azerbaijan (Mingachevir).

United Kingdom) (Fig. 2). There is a clear concentration in EU-27 countries[27] with 2020 A-CAPs (92% of the total) being from the EU. Further details on the geographical distribution of the A-CAPs are provided in Supplementary Information 4.

Results

First, we present how cities perform across the six ADAQA-GCoM components (1. Fact Base; 2. Adaptation Goals; 3. Adaptation measures; 4. Implementation; 5. Monitoring and Evaluations; 6. Participation) and in terms of consistency, through four internal consistency checks (Fig. 1). Secondly, we set out the findings of a statistical correlation analysis checking the similarity of the overall ADAQA-GCoM and its component scores within and across different spatial units and jurisdictions. This has a particular focus on the influence of city size and nationality. We then present how the scores evolved from 2007, when the Paris adaptation plan was approved, up to the cut-off date of the analysed GCoM's MyCovenant

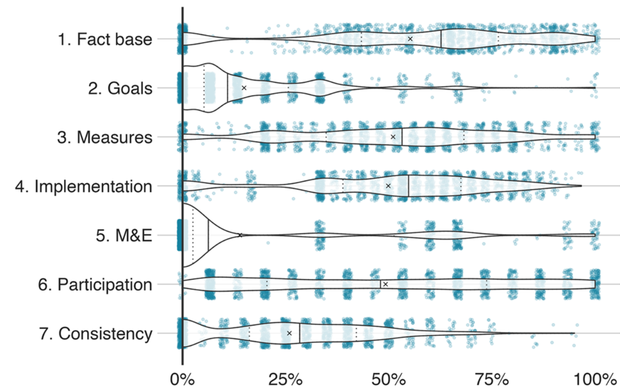

Fig. 3 | Component scores of all 2205 A-CAPs within the sample. Each dot represents a city, and the violin plots represent the distribution of the dots. The continuous vertical bars within the violins represent the 50% percentiles; dashed lines represent the 25% and 75% percentiles, respectively. The x-shaped cross represents the Mean.

dataset[30] in January 2024. We also examine whether any trends may be associated with a range of city characteristics. Further details on the adopted methodologies can be found in the Methods section.

Performance across the ADAQA-GCoM components

We identified substantial heterogeneity across the 2205 A-CAPs in the sample, although patterns emerge when each component is investigated individually (Fig. 3). Generally, cities perform well on *Fact base*, *Measures*, and *Implementation* (components 1, 3, and 4), while they tend to score lower on *Goals*, *M&E* (components 2 and 5), and, to a lesser extent, on *Consistency*. Most often, cities cluster around a particular score for each component, meaning that they are relatively similar in addressing that aspect. With respect to *Goals* and *M&E*, for example, they cluster around the low end (<10% percentiles), and for the *Fact base*, *Measures* and *Implementation* components they cluster around medium scores of 50–60% percentiles. In contrast, scores for participation are highly diverse, with an almost even distribution of cities spreading from 0 to 100%.

Most plans provide a high level of detail when describing the local climate context with current and future data projections (the first component of ADAQA-GCoM, *Fact base*). Climate action plans typically include comprehensive climate data, detailing both current conditions and future projections. For example, 65% of A-CAPs identify at least five climate hazards. However, while the GCoM framework enables cities to tailor methodologies to their local contexts and available data, some cities continue to encounter difficulties due to outdated or limited data. Furthermore, 70% of the plans fail to identify vulnerable groups, and only 7% consider future risks over more than one of three timeframes (short, medium, and long term). In terms of defining *adaptation goals*, 74% of plans include at least one, but only 20% of them link these targets to specific hazards, and many lack measurable, quantitative goals. For the third component, which relates to suggested or planned *adaptation measures*, 54% of plans set out measures for more than five sectors. At the *implementation* level (the fourth component), A-CAPs also fare very well: 85% of plans identify a responsible party for implementation, and 88% include a timeline for implementing actions - although only 32% allocate a specific budget for adaptation.

However, 82% of A-CAPs do not explicitly identify vulnerable populations. In general, equity considerations in relation to the defined *adaptation measures* are frequently absent, potentially because they are also not mandatory in the Risk and Vulnerability Assessment. *Monitoring and evaluation (M&E)*, which represents the fifth component, is another weak element within the plans. Only 9% of plans submitted monitoring reports on time, and just 7% actively monitored their goals. While stakeholder participation (the sixth component) is almost always

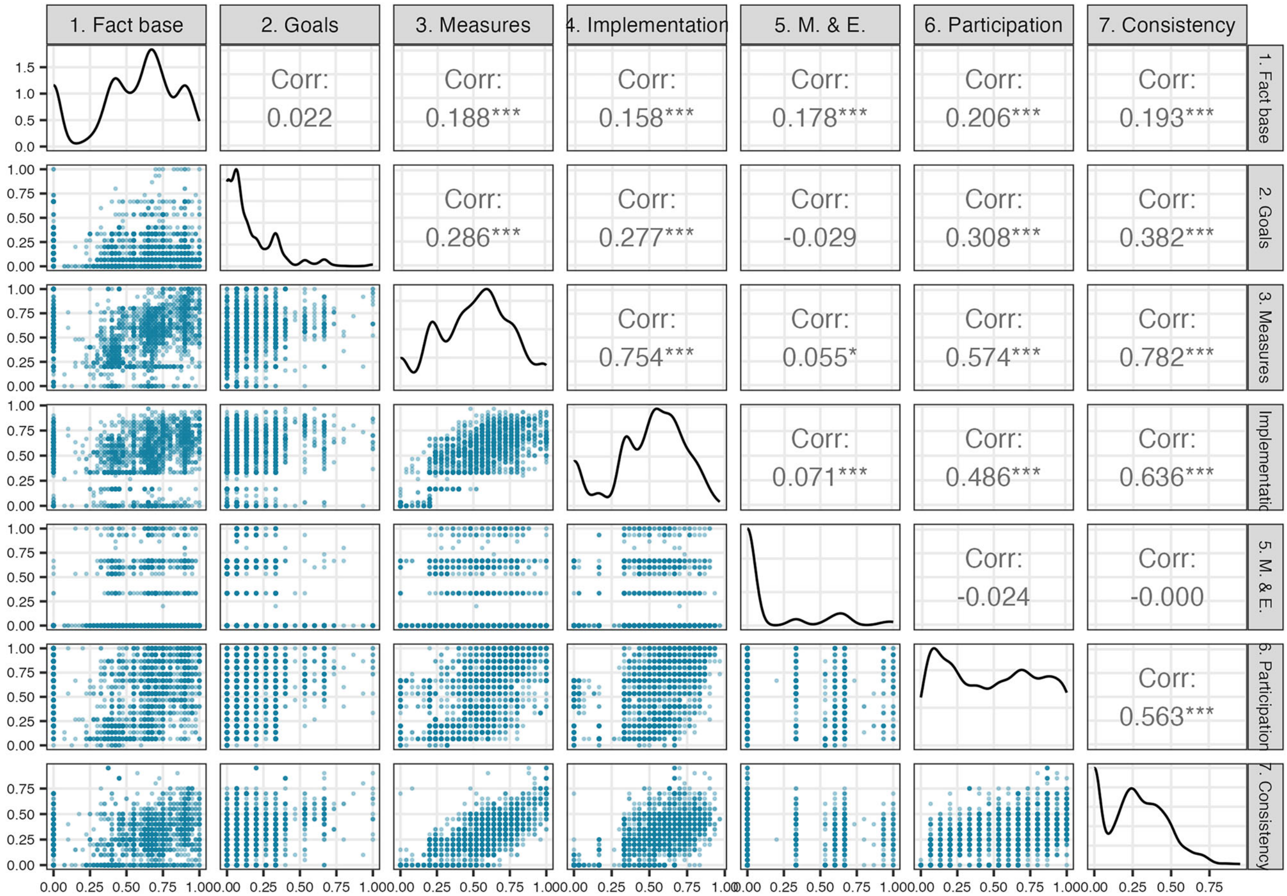

Fig. 4 | Correlations among ADAQA-GCoM components for all the cities. This figure shows a pairwise comparison of the scores, with the diagonal displaying the density of the respective indicator (correlation plot made using GGally R package[52]).

present, it is rarely extensive: only 21% of the plans involve more than five groups of stakeholders, and the methods of involvement are described in only 53% of cases. Finally, internal *consistency* (the seventh component) between the different sections of the plans is sometimes extremely limited. Although 41% of A-CAPs demonstrate good alignment between vulnerable sectors and proposed actions, only 0.8% of plans explicitly align identified hazards to goals, and just 6% effectively address the needs of vulnerable populations. The performance is slightly better regarding the alignment between identified hazards and planned measures: 23% of A-CAPs achieve a consistency greater than 60%, but only 11% achieve a consistency of 100%. A full and detailed discussion of the results for each indicator and component can be found in Supplementary Information 3, Supplementary Tables 3.1–3.7.

Correlation between the ADAQA-GCoM components, national influence, and city size

There are strong and positive correlations between the ADAQA-GCoM components and consistency (Fig. 4), which means that scoring well on one component generally tends to be associated with scoring well on other components. Notably, the score on *Implementation* is significantly and positively correlated with all other components, meaning that the implementation section and information is usually good if all other sections of an A-CAP are also of high quality (and vice versa). This pattern may partly reflect the structure of the MyCovenant data, in which implementation indicators and adaptation measures are recorded in the same table, whereas other data come from separate tables. This organizational layout may explain why implementation correlates with the other components, as it likely captures a city's inherent ability to integrate and coordinate various aspects of its adaptation plans. *Implementation* is particularly strongly correlated with the score on *Measures* (the correlation is 0.75): only a handful of cities do not achieve similar scores for *Implementation* and *Measures*.

The component which appears the least correlated with others is *M&E*. It is not statistically correlated with any other components, apart from a weak correlation with *Fact base* and *Implementation*. Many cities have a zero score on *M&E*, while having high scores on other components.

However, while cities tend to achieve similar scores across components, only a small fraction of cities score highly (>75%) on several components (Fig. 5). For example, only five cities score highly on five components or more, whereas nearly a quarter (23%) score well on just one component, and more than half (54%) do not achieve high scores on any component (Supplementary Information 5). Interestingly, a specific country or national pattern (Supplementary Fig. 5.4) does not correlate with the highest scores across many components, and city size is only slightly associated with these top performers. Cities with high scores in up to five components are generally a bit larger (between 10,000 and 100,000 inhabitants) than those that score high on four, three, two, or one component(s), but this relationship is not statistically significant. Also, there is substantial heterogeneity amongst the medium-sized cities of 10,000–100,000 inhabitants: some score well on almost all components, and others score well on none (Fig. 5).

The geographical distribution of average total scores at the NUTS3 level (Nomenclature of Territorial Units for Statistics[31]) reveals substantial heterogeneity (Fig. 6), which confirms the findings of the statistical analysis. A visual representation shows how the dark blue areas, representing the highest values, are relatively evenly distributed across the territory. In contrast, the NUTS3 areas with the lower scores (yellow) are fewer in number.

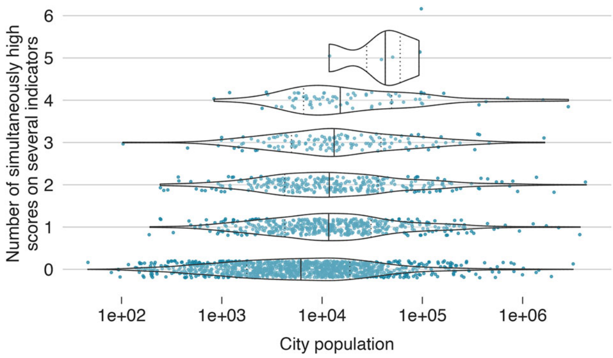

Fig. 5 | City size and simultaneously high-scoring components. This figure shows that there is a slight correlation between having a higher population and achieving high scores across many components simultaneously. However, it also shows that many cities with a higher population than the top five best-performing cities do not score highly on any component.

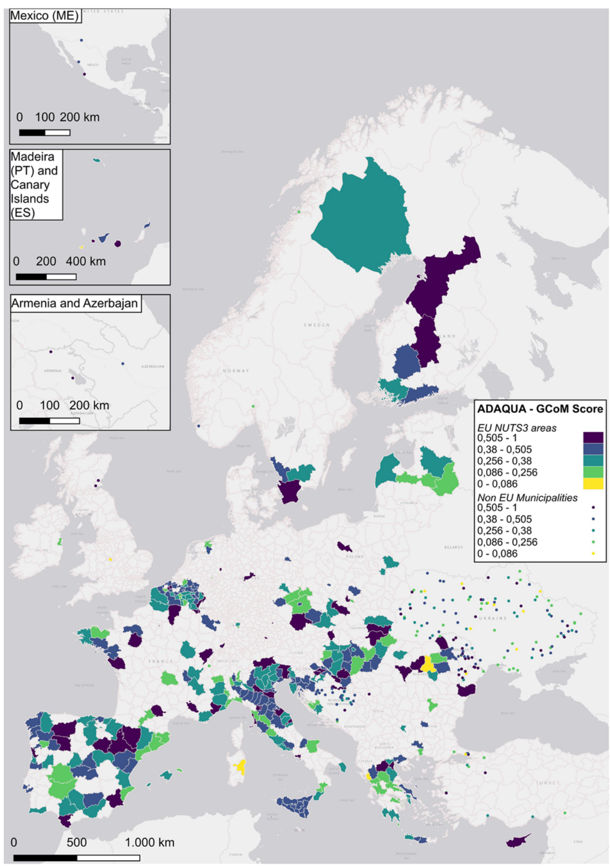

Fig. 6 | Distribution of the mean of the total score obtained by each A-CAP within the NUTS3 areas. The map shows the distribution of mean values using a graduated colour scale. The classification ranges are uniform for both points and NUTS3 areas and have been defined using the Jenks method[53]. In countries outside EU-27, without a NUTS3 classification, each A-CAP is represented by a coloured point according to the same scheme used for NUTS3 areas. NUTS3 areas not included in the dataset are shaded in light grey.

Based on the same cartographic design of the map in Fig. 6, we created seven maps to show the similarities and differences in the mean scores for each component of ADAQA-GCoM at the NUTS3 level (see Supplementary Fig. 7.1–7.7). For each map, we adopted a colouring scheme consistent with that used for the components (Fig. 1).

On examining the geographical distribution of each component individually, we observe that NUTS3 areas are all characterised by significant heterogeneity in their scores, although some peculiarities can be identified. Interestingly, some NUTS3 areas with high and localised average total scores, such as Belgium, the Italian northern Apennine areas, and Sicily, do not necessarily perform consistently across all individual components. This suggests that the quality of the various dimensions evaluated by ADAQA-GCoM varies considerably: certain components receive high scores in some NUTS3 areas, while others are significantly lower. Nevertheless, the overall level remains high when these elements are averaged across the NUTS3 area.

Evolution of ADAQA-GCoM component scores over time

Figure 7 shows how the scores for each component of an A-CAP evolve over time (spanning from 2007 to 2023 (since no A-CAPs were included in the GCoM's MyCovenant dataset in 2024)).

In comparing plans across different cities and years, we followed the approach found in Reckien et al.[4] by focusing on common quality indicators to identify overarching trends. This approach addresses temporal and geographical differences, though it may not fully capture the localized contexts or historical evolutions specific to each city. Therefore, while the findings offer valuable insights into general trends, they should be interpreted with caution and considered as a foundation for more detailed, city-specific analyses. The trend of the *Fact Base* component remained stable initially, peaked around 2020, and has since been on a downward trajectory, while *Monitoring and Evaluation* has continually decreased over time. In contrast, the *Adaptation Goals*, *Adaptation Measures*, *Implementation*, *Participation*, and *Consistency* components have all exhibited an upward trend, indicating that cities are making progress in these areas over time.

The GCoM's MyCovenant dataset of municipalities with an A-CAP is highly heterogeneous (see Supplementary Information 4). It gathers 2170 signatories from municipalities with populations as low as a few hundred inhabitants and cities up to several million people. The spatial distribution, particularly in EU-27 countries, is also far from uniform, with the vast majority of cities being located in a few countries and, within them, a few regions (Fig. 2). While this complicates statistical analysis, we can undertake meaningful comparisons within subsets of the database.

For example, the 84 largest cities (those with more than 200,000 inhabitants) are well scattered across countries (Supplementary Fig. 4.2). Their individual scores for each component of ADAQA-GCoM, as well as the correlations between the scores (Supplementary Fig. 5.2), are similar to those found for the whole sample (Fig. 4). This shows, again, that large cities in the GCoM database do not generally, and not statistically significantly, fare better or worse than jurisdictions of other sizes (Fig. 8). No clear geographical pattern emerges, neither between countries nor between EU-27 regions (Supplementary Table 6.7).

Influence of city characteristics and spatial proximity

A large proportion of cities in 6 NUTS1 regions in 3 countries (Belgium, Italy and Spain) joined the GCoM initiative thanks to the active role of Covenant Coordinators[32] (Fig. 2, Supplementary Information 6). Within these regions, 56% of all cities in Italy, 29% of those in Spain and 94% of those in Belgium joined the GCoM. Among the GCoM signatories, 16%, 35%, and 81% have an adaptation plan, respectively. Closer examination of these cities enables us to reduce selection bias and study the influence of city characteristics on component scores within a given territory (Supplementary Information 6.1).

In this sub-sample, some of the overall ADAQA-GCoM scores, as well as those for their individual components, appear to be significantly associated with city populations and Eurostat territorial typologies (Supplementary Information 6.1). However, relationships are different in each country. The number of inhabitants, for instance, has a moderate positive influence on the component *Fact base*, but this influence is only significant in Italy and Spain. In Belgium, being in a "predominantly rural" NUTS3 region, as defined by Eurostat, is significantly associated with higher scores

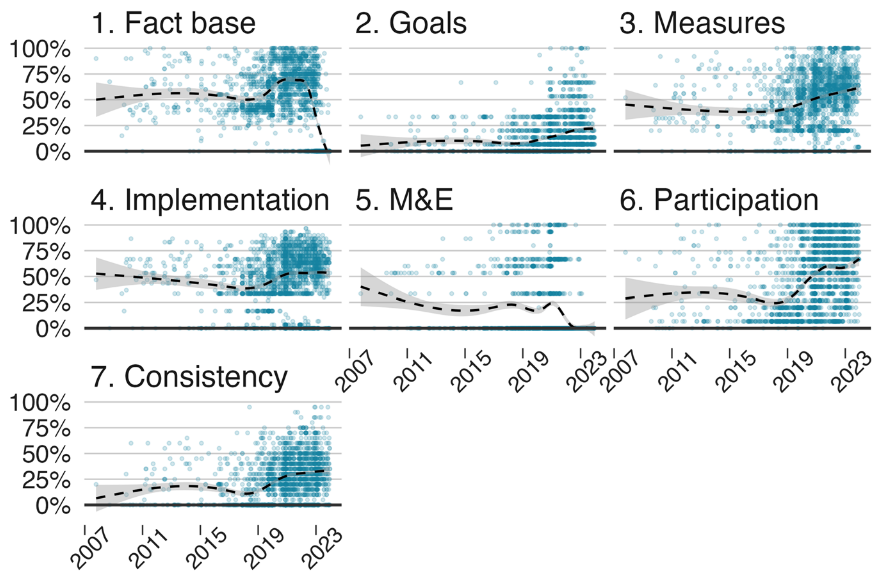

Fig. 7 | Trends in the scores for each component for all cities in the GCoM's MyCovenant dataset. The timespan covers plans from 2007 to 2023.

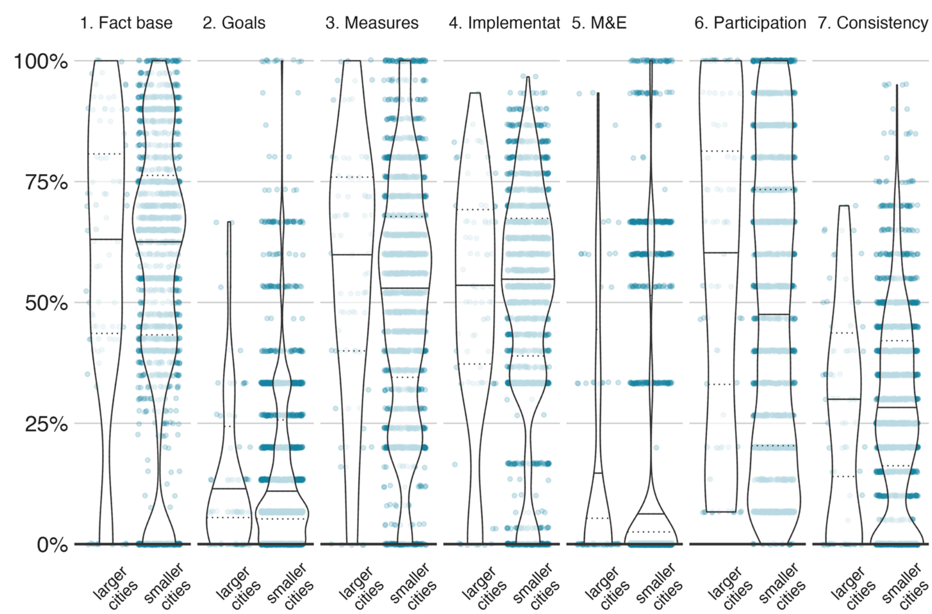

Fig. 8 | Component score distributions by city size. Violin plot of the component scores for 84 larger versus smaller cities, i.e., cities with populations above and below 200,000 inhabitants.

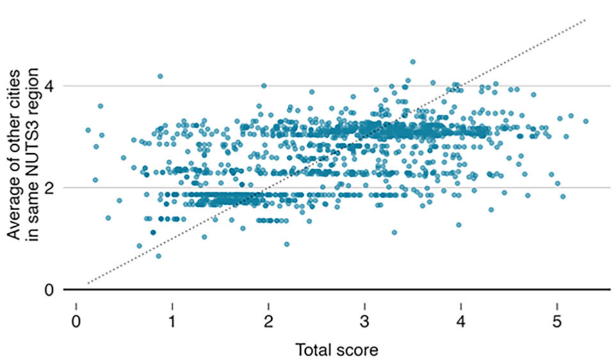

Fig. 9 | Spatial correlation of ADAQA-GCoM total scores. Correlation between the total score of a city and the average of the total scores of other cities within the same NUTS3 region.

for the *Measures* and *Implementation* components, but in Spain it is associated with lower scores. This reflects differences in the institutional frameworks under which the plans have been developed in each region.

However, a pattern that appears stable in all the countries of the sub-sample is the influence of spatial proximity: the total ADAQA-GCoM scores of cities that belong to the same NUTS3 regions are strongly correlated (Fig. 9 and Table 1; see also Supplementary Information 6.3). The average of the scores of the other cities belonging to the same NUTS3 region is a significant predictor of the scores of each city, a result that is valid in all three countries. Similar results can be found for NUTS2 and NUTS1 regions, and even for countries, but the explanatory power of the correlation decreases as the administrative unit increases in size. This means that ADAQA-GCoM and component scores are most similar to cities nearby. The similarity is still significant, but the association weakens cities further away, i.e., the larger the spatial unit.

In contrast to Italy and Belgium, Spain exhibits significant heterogeneity in the quality of plans, with no discernible regional patterns (Fig. 10).

This suggests that the quality of the plans depends on other factors, e.g., individual risk perception, local political priorities, and the technical capacity of municipalities, consultants, and local networks, rather than on national or regional coordination and characteristics. Regions in Belgium, and in some areas of Italy, including north-eastern Italy, the northern Apennine areas, and Sicily, demonstrate greater homogeneity in scores. The Sicilian Region, recognizing the opportunity offered by the Covenant of Mayors network for its municipalities, centralised the disbursement of funds to them after the JRC approved the plans[33]. The drafting of the plans remained the responsibility of the individual cities, which worked with the support of consultants.

Table 1 | Correlation coefficients for the relationship between component scores of one particular city and averages of components of other cities in the same NUT1, NUTS2, and NUTS3 areas, as well as the national, country-level average

Indicator	NUTS1-level variation	NUTS2-level variation	NUTS3-level variation	Country-level variation
Total	0.48***	0.53***	0.55***	0.36***
1. Fact base	0.37***	0.48***	0.55***	0.09***
2. Goals	0.30***	0.41***	0.42***	0.20***
3. Measures	0.45***	0.53***	0.57***	0.43***
4. Implementation	0.35***	0.42***	0.49***	0.30***
5. M&E	0.33***	0.36***	0.42***	0.19***
6. Participation	0.57***	0.57***	0.60***	0.50***
7. Consistency	0.39***	0.43***	0.47***	0.37***

$^{+}p < 0.1$; $^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$.

In Belgium, the Covenant Coordinators have played a crucial and highly effective role in supporting municipalities. Due to their coordination and technical assistance, many local authorities have successfully developed and implemented their plans, thereby strengthening the initiative's overall effectiveness[34]. In both cases, highly integrated multilevel governance arrangements emerge as a key factor in the initiative's success.

Finally, the patterns across Figs. 3–10 reveal a structural imbalance in adaptation planning: diagnostic rigour is weakening even as operational action expands. Cities are advancing on implementation and participation, but the declining quality of their Fact Base and Monitoring & Evaluation components points to an implementation bias that limits adaptive learning. The strong spatial clustering of performance within NUTS3 regions (Figs. 6, 9–10) shows that regional governance frameworks, such as those operating in Belgium and Sicily, can drive consistency and raise overall quality, compensating for local capacity gaps. Yet participation remains uneven, with only a small fraction of plans addressing vulnerable groups directly. These results highlight the need for sustained investment in evaluation capacity, regional coordination, and social inclusion. Embedding ADAQA-GCoM as a dynamic benchmarking system would allow the GCoM to track not only progress but also quality, equity, and learning capacity over time, enabling dynamic monitoring rather than static evaluation and directly linking local progress to the Belem indicators framework.

Discussion

In this study, we presented ADAQA-GCoM, an enhanced tool specifically designed to assess the quality of urban climate adaptation plans submitted to the Global Covenant of Mayors network. We used ADAQA-GCoM to demonstrate how differences in the quality of the Climate Action Plans (A-CAPs) of Global Covenant of Mayors signatories are associated with certain city and spatial characteristics. We suggest that better quality plans can

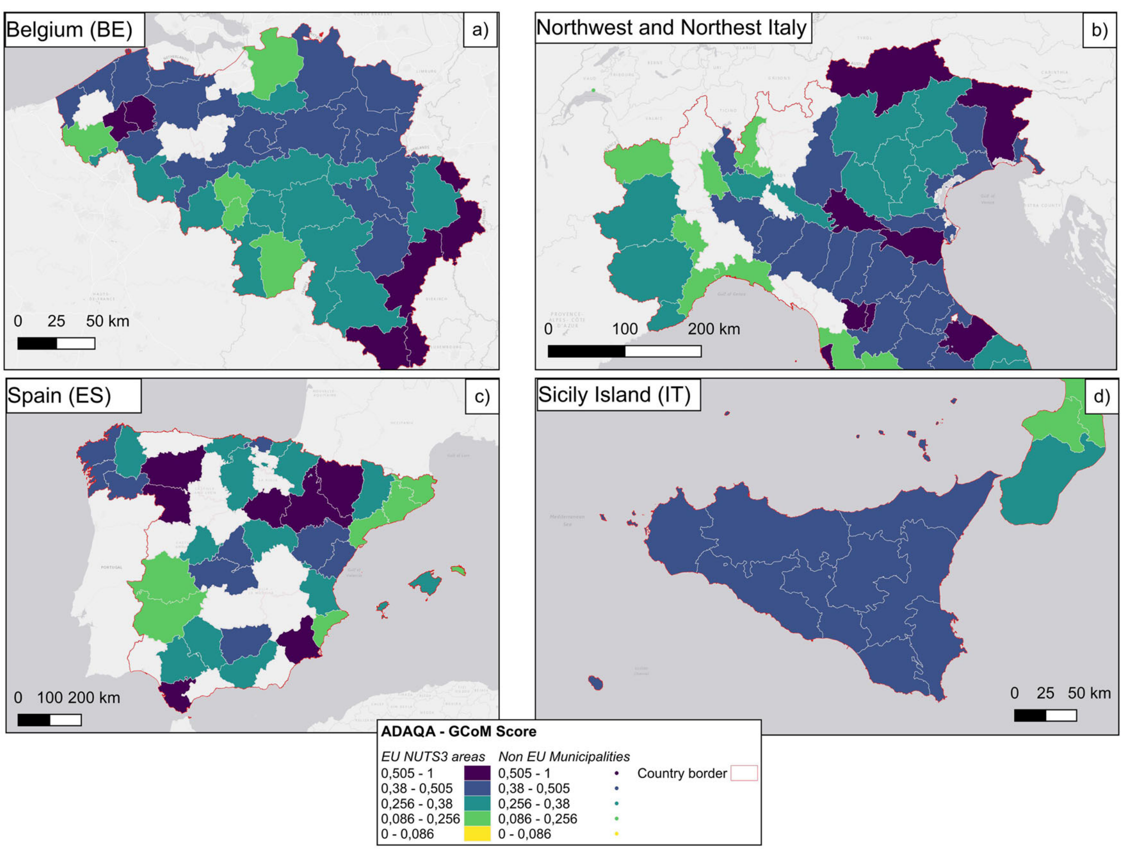

Fig. 10 | Spatial distribution of A-CAP total scores at the NUTS3 level. The map shows the distribution of the mean of the total score obtained by each A-CAP within NUTS3 areas in selected regions of Belgium, Italy and Spain. The colour scales and classification ranges are consistent with those used in Fig. 6.

promote urban climate resilience and foster implementation of the measures set out in A-CAPs.

Overall, we found substantial heterogeneity of total ADAQA-GCoM scores across the sample of 2205 A-CAPs, but patterns emerge when analysing individual components of plan quality, or subsets of signatories that are geographically more similar. On average, plans score highly in the components of *Fact Base, Measures, Implementation*, and *Participation*. Plans score lower on *Goals*, and *M&E*, and partly on *Consistency*. These findings are similar to those of other recent studies on cities in EU-27 countries[4,29] and reinforce previous observations that developing good M&E procedures can be challenging. Notably, Reckien et al.[4,29] (using a different sample of cities) highlighted that, of the components of plan quality, goal-setting had improved the most in recent years, whereas our study found that this aspect was quite weak. Goal-setting, ideally incorporating clear, quantitative and measurable targets, is a key component of good adaptation plans, as it lays the foundation for subsequent stages of the adaptation process, namely selecting measures and undertaking monitoring and evaluation. Climate plan goals in our sample of A-CAPs of the GCoM are often generic or politically oriented, despite guidance from the JRC guideline[35] and UAE Belem Work Programme[36], leading to low scores in consistency regarding hazard-specific objectives. We argue for more global standards in the goal setting of climate adaptation plans. While the scores for most components are clustered, i.e., similar across cities, the scores for *Participation* are very diverse, ranging equally from very low to very high scores. This seems to be a particular strength of the GCoM reporting framework, which stresses the importance of participation and the consideration of vulnerable groups. Adaptation plans that are developed independently of national or international reporting guidelines tend to neglect these key issues[4,29]. However, although our study found that cities do involve stakeholders to a certain extent in policymaking, this does not necessarily result in excellent plans, because internal consistency across urban adaptation plan components (specifically, whether cities consider the interests of vulnerable groups and sectors and involved them in decision-making) appears weak. This inconsistency could be due to resource constraints, limited participatory expertise, or insufficient guidance. It highlights the need for further and improved integration of these groups and the outcomes of that integration, e.g. by accounting for their voices and needs, in the adaptation process, to ensure that identified vulnerabilities, overarching goals, proposed actions, and *M&E* are effectively aligned.

Although cities tend to achieve either high or low scores for more than one component (if they perform well in one area, they tend to do so in another), only a minority of cities manage to score highly across many components. This suggests that developing comprehensive high-quality plans is still a difficult task for most local governments, and high-scoring plans are the exception. However, there is no correlation between a specific country or national model and those cities with the highest scores across many components and only a small association with city size, but this is not significant. In contrast to other studies[37–40], large cities in the GCoM's MyCovenant dataset do not generally, and statistically significantly, fare better or worse than municipalities of other sizes. This suggests that a uniform adaptation support framework, such as the one provided by the GCoM and its reporting platforms, can compensate for some of the capacity constraints that affect smaller cities. This represents a particular success of the GCoM approach[41–43].

We identified a steady increase in scores for the *Goals*, *Measures*, *Implementation*, *Participation*, and *Consistency* components since 2007. Scores for the *Fact Base* component have fallen recently, and scores for M&E have declined progressively over time. The initial stability and eventual decline in the *Fact Base* score may reflect cities' early emphasis on building a robust foundation of data and risk assessments to underpin their adaptation planning, before shifting resources and focus to other areas of action and implementation. The shift in the quality of *Factbase* may also stem from resource constraints after the 2020 climate awareness peak (and subsequent years of COVID-19). The consistent decrease in *Monitoring and Evaluation* (M&E) scores suggests that cities might be struggling with implementing effective tracking systems or allocating resources to continuously assess their adaptation progress. This could be due to a lack of clear guidelines, the difficulties associated with developing measurable targets for adaptation, insufficient capacity, or the challenges of integrating monitoring into existing planning processes. In this context, current efforts to support professionals around the world by defining truly usable adaptation metrics through the UAE Belem Work Programme may prove helpful. This Programme published its final list of indicators in September 2025, reducing an initial collection of around 9,000 indicators first to a set of 490 and subsequently to a final set of 100 indicators[36]. Conversely, the upward trends in Adaptation *Goals*, *Measures*, *Implementation*, *Participation*, and *Consistency* may result from increased awareness of climate risks and political commitment, alongside better funding and collaboration opportunities. Engaging stakeholders provides valuable insights that help refine strategies, while access to best practices and case studies from other cities offers guidance, improving consistency and effectiveness in adaptation efforts.

The strong positive correlations between ADAQA-GCoM components suggest that cities that excel in one area of adaptation planning tend to perform well across others, indicating a comprehensive approach to climate action planning. Notably, the strong correlation between *Implementation* and other components, especially *Measures*, suggests that cities with well-developed measures also tend to provide detailed, actionable information for the implementation of their adaptation strategies. In contrast, the weak correlation of *Monitoring and Evaluation* with other components might stem from funding primarily allocated to plan creation, which leaves M&E underfunded, less robust, and disconnected.

Overall, the GCoM's MyCovenant adaptation planning dataset is extremely heterogeneous. It includes a total of 2170 cities that have populations varying in size from hundreds to millions of inhabitants. Although the GCoM is a global alliance for city climate leadership, most of the signatory cities are located in EU-27 countries, and a disproportionate number is concentrated in a few other European countries and regions. However, this spatial concentration allows meaningful comparisons within subsets of the database, which enabled us to test for other correlations and potential explanations.

For example, we found that proximity matters within our sub-sample of Belgian, Italian, and Spanish cities and regions. Total scores for the ADAQA-GCoM tool, as well as its individual components, are most similar for cities close to each other. Scores are significantly similar for cities within the same NUTS3, NUTS2, NUTS1-region and country, but the degree of similarity falls as the size of the spatial unit increases. Several reasons could explain these correlations: for instance, cities could rely on data or methodologies proposed by regional authorities, which could lead to adaptation plans sharing many similarities[44,45]. Cities close to each other may also be confronted with similar climatic challenges, impacts, hazards, or risks, or be inspired by the ideas or approaches of their closest neighbours[43,46]. Additionally, regional governments in the three national contexts play important roles within their multilevel systems[47,48], and may incentivize joint local action through climate policy frameworks. This is, for example, the case in the Sicilian Region, where the disbursement of funds for GCoM signatories was centralised after the JRC approved the plans[33]. The same applies to regions in Belgium, where the Covenant Coordinators provide coordination and technical assistance, effectively supporting urban climate planning in signatory cities[41]. More generally, we need more data and research to identify the influence of these regional mechanisms on local adaptation planning.

In summary, we presented a customized assessment tool, the ADAQA-GCoM, and applied it to the 2205 cities involved in the GCoM initiative with accessible A-CAPs. The analysis highlighted some strengths of local adaptation plans and identified critical points where cities and network coordinators need to improve. To this end, our framework can be used to support a dual self-learning process for both cities and legislators/regulators. By highlighting some weaknesses in plans, it supports local governments in developing and enhancing their approaches to climate adaptation. By providing a comparable adaptation plan quality assessment framework, it can help to generate new guidelines for checking submissions, evaluating plans, and drafting credible[3] and adequate[49] approaches to urban adaptation for government bodies, the JRC or other international organisations. It therefore represents a more sophisticated approach to evaluating adaptation plan quality, which we hope will lead to better adaptation planning and implementation practices at the local level, both within and outside the Global Covenant of Mayors.

Finally, notwithstanding its contributions, this study has certain limitations that should be considered. Firstly, our work refers generically to cities that are involved in the GCoM and have developed an A-CAP. However, reality is more complex considering that the sample also includes Unions of Municipalities and Joint A-CAPs created by neighbouring municipalities, as well as metropolitan cities with different jurisdictions and separate plans (for example, Budapest and its districts have ten A-CAPs). The number of cities involved in GCoM is not easy to define or count, and hence it is more accurate to refer to signatory cities. Secondly, although these cities are part of the global GCoM transnational network, they may not be considered representative of the current state of urban climate adaptation planning worldwide. This is because 92% of signatories are in 24 European countries. Thirdly, our analysis is based on data from the MyCovenant platform, provided voluntarily were self-reporting by municipalities, potentially lead to distortions in the data collected. Lastly, the scoring process has an inherent subjective nature, given that scores were assigned based on expert judgment, using a linear functional that assigned a score of zero for an indicator value of zero, with scores increasing proportionally to a maximum of 5 for each indicator, corresponding to the optimal value. For instance, in the case of adaptation actions, a plan with five actions was deemed optimal and awarded the highest score of 5, while plans with 50 actions would still receive the same maximum score. Additionally, cities with plans that lacked data for certain indicators automatically received a score of zero for those indicators. This approach may affect the accuracy and objectivity of the evaluation, as it relies on expert judgment and the availability of data.

Methods

This section introduces the sample plans selected for this study and describes the methodology we adopted. It begins by outlining the main stages of the work and then describes the tool we used to assess the quality of urban adaptation plans.

The sample of plans

The analysed sample consists of 2205 Climate Action Plans (CAPs) that reported information on the adaptation pillar (A-CAPs) and were submitted to the Global Covenant of Mayors via its MyCovenant platform by January 2024[30]. In particular, 92% of the analysed A-CAPs (2018 plans) are concentrated in 24 of the 27 EU countries (Denmark, Lithuania and Malta do not feature). Spain has the most plans (836, or 37.9% of the total global sample of A-CAPs), followed by Italy (565, 25.6%) and Belgium (314, 14.2%). More information is reported in the Supplementary Information 4. The overall body of A-CAPs covers 14% of the EU-27 population, according to the 2021 census[50]. The remaining 8% (185) of A-CAPs were developed by cities in an additional 11 countries outside the EU-27, namely Armenia (2), Azerbaijan (1), Bosnia and Herzegovina (26), Mexico (3), Norway (3), the Republic of Moldova (27), Serbia (1), Switzerland (1), Turkey (15), Ukraine (103) and the United Kingdom (3).

Overview of the main methodological steps

We began by conducting a thorough literature review that focused on identifying the key needs, effective methodologies, and lessons learned from previous studies that assessed the quality of urban adaptation plans. As the research framework became clearer and gaps emerged, we developed the key research objectives set out in the introduction, which guided both the choice of methodological approach and the sample of urban adaptation plans.

In parallel, we sought to identify a reference tool to assess the quality of urban adaptation plans (A-CAPs), based on the results of the literature review. We settled on the ADAQA tool, developed within the EURO-LCP initiative, which has already been tested and applied to a sample of 327 cities in the EU-27 and the UK[4]. Although ADAQA generates its results through the completion of a survey with predefined questions based on 6 components, tailoring it to the very complex structure of the GCoM's MyCovenant dataset required several steps, calibration efforts and continuous refinement before we settled on a final configuration, which we called the ADAQA-GCoM.

In particular, we customized the ADAQA reference assessment tool to fit the structure and data within the adaptation pillar of the GCoM's MyCovenant dataset[30]. This involved careful comparison and alignment of the ADAQA components with the content of the A-CAPs in order to create an automated data extraction and usage process, and to perform a quality check within the GCoM's MyCovenant dataset. This was followed by a calibration test using the results obtained from applying the ADAQA-GCoM tool to the sample of cities with an A-CAP submitted by December 2023[30] and by undertaking subsequent tweaks and changes to the framework.

At the end of this iterative process, the new tailor-made scoring tool for A-CAPs, the ADAQA-GCoM, was applied to the A-CAPs of the entire GCoM's MyCovenant dataset. The results obtained, i.e. the scores assigned to each A-CAP in the sample, were analysed both in terms of number of plans and relative total scores per component and per indicator (Supplementary Tables 3.1–3.7), and by applying statistical correlation analysis to check for similarities.

We applied this statistical correlation analysis to a selected sample of A-CAPs to identify possible relationships between the six components, and the four consistency checks of ADAQA-GCoM for all A-CAPs (Fig. 4). Due to updates, 35 cities had submitted two A-CAPs. Here, the most recent ones were used to carry out statistical analysis, resulting in a sample of 2170 plans. We also examined how belonging to a specific country (Supplementary Fig. 5.3) and city size (Fig. 5) influenced the performance of those cities with the highest scores in several components.

We then analysed the influence of city characteristics and spatial proximity by regressing the ADAQA-GCoM scores and their individual components by population and urban-rural typology, while controlling the NUTS1 regions in which cities are located. As explained in the main text, this analysis was carried out in six NUTS1 regions in Belgium, Italy and Spain – the three countries in which around two-thirds of the cities are located.

Figure 11 provides an overview of the workflow through the different stages of the research, highlighting the relevant connections between one stage and the next. The following section describes each step in more detail.

Customization of the ADAQA assessment tool

The development of the ADAQA-GCoM tool required a careful customization of the ADAQA evaluation framework to the structure and data reported in the A-CAPs, based on the following operative steps:

1. Comparing the six ADAQA components and the five ADAQA consistency measures with the main sections of the GCoM Common Reporting Framework - adaptation pillar[26], the Reporting Guidelines[51], and the GCoM open dataset structure[27].
2. Checking the ADAQA questions against the entries in the GCoM's MyCovenant dataset. This step led to the alignment of the ADAQA components with the A-CAPs content, as well as to the identification of new indicators when a perfect match could not be found (Supplementary Information 2). It also took into account the fact that cities are required to report some data, and that some data have been modified over the years. Where available, additional indicators were incorporated to generate a more comprehensive assessment of each component, whilst also avoiding redundancy.
3. Refining and calibrating ADAQA-GCoM with the GCoM's MyCovenant dataset, analysing test results, and implementing possible corrective/improvement procedures through three successive versions. Each version was developed through an iterative process, which was built on the previous one and was further refined according to the specificities of the GCoM sample. A final set of 28 indicators was

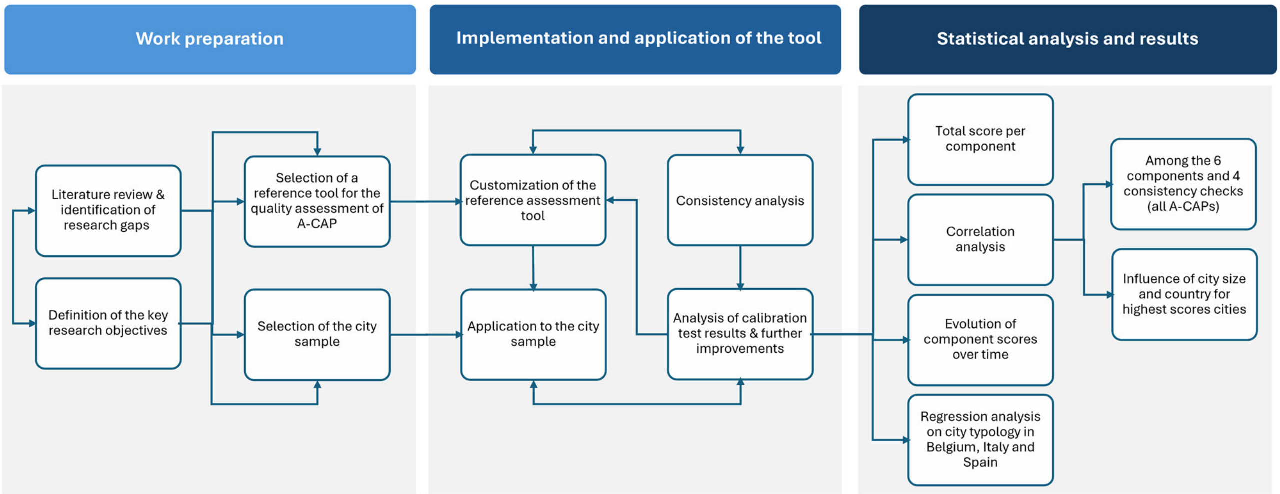

Fig. 11 | Overview of the main methodological steps.

selected and calculated for the entire dataset, grouped into components and consistency checks. Details of the ADAQA-GCoM indicators and associated scores for each indicator can be found in Supplementary Information 1.

4. Undertaking an ad hoc automated data extraction to convert and normalise each value with scores ranging from 0 to 5, where 0 represents the minimum possible value or absence of value, while 5 signifies the maximum possible value or the optimal value as determined by experts. This was necessary because each of the 28 indicators had its own scale of measurement (counts, percentages, etc.). The maximum achievable scores for each indicator and component are listed in the Supplementary Tables 1.1–1.7.

Consistency analysis of A-CAPs through the ADAQA-GCoM

A comprehensive consistency check is a necessary part of any thorough evaluation of plan quality, to ensure coherence across its various components. This process involves verifying that actions are directly aligned with adaptation goals and identified hazards (as set out in the Fact Base and Risk and Vulnerability Assessment). For instance, if the goal is to enhance resilience to heat waves, it should be supported by actions like planting trees to create shaded areas or providing shaded pathways. Additionally, if a plan identifies the impact of heat stress on vulnerable populations such as the elderly as a key climate risk, this should be addressed by specific targeted actions.

The accuracy of the ADAQA-GCoM tool is ensured through a two-level approach:

1. The internal coherence check is implicit in the GCoM's MyCovenant dataset. Together with timeliness, completeness, quantification, and progress, this comprises one of the five sub-components of the more general evaluation criteria developed by JRC[28] to assess A-CAPs and provide feedback. Specifically, this check verifies that all the high-risk hazards, highly vulnerable sectors and vulnerable population groups identified in the RVA, as well as the hazard-specific goals, are matched by at least one corresponding action.
2. An assessment of whether all sections of the A-CAP align, based on the four criteria considered in the consistency checks of ADAQA-GCoM (Supplementary Table 1.7). This evaluation is like the ADAQA internal consistency check approach in ref. 4.

Data availability

The GCoM dataset cited in the manuscript refer to reference[30]. The dataset to which we refer here, which ispublished in Zotero, contains the results of applying the ADAQA-GCoM to the 2,205 A-CAPs analysed in this paper. Toavoid ambiguity, we have standardised the reference to the GCoM, using the term 'GCoM's MyCovenant dataset'throughout the text.

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Author contributions

F.P., A.T., D.R. and M.S. conceptualized the study. F.P. and A.T. developed the ADAQA-GCoM tool. V.V., in collaboration with D.R. and A.T., conducted statistical analyses. F.P., V.V., M.S., and L.S. developed the figures. F.P., A.T., D.R., M.S., V.V., L.S., A.B., P.E., K.R., D.G., B.I., S.G., S.D.G.H., A.K.R., A.M.F., H.O., P.F., P.B., M.S.C., O.H. and E.F. contributed to the writing and editing process. All authors have read and approved the manuscript.

Competing interests

The authors declare no competing interests.

Additional information

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