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Adaptation to climate change in cities of Mediterranean Europe

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ABSTRACT

Cities across Mediterranean Europe face common climatic threats. They are highly vulnerable and very likely to suffer losses and damages due to heat waves, droughts, wildfires, landslides, and extreme coastal events. To this date, however, there is no systematic understanding of how cities in Mediterranean Europe are preparing to adapt to these impacts. To address this question, we analyse local adaptation plans in 73 cities located in 51 regions across 9 European countries along the Mediterranean Sea (France, Italy, Spain, Greece, Portugal, Croatia, Slovenia, Cyprus and Malta). We also investigate upper levels of planning to understand the influence of policy environments. Across the sample, 67 % of regions have adopted a plan, but only 30 % of the cities. The most common climate-related hazards these cities prepare for are extreme temperatures and rainfall, followed by drought and water scarcity, as well as floods and landslides. Without legal obligations, neither regional nor national adaptation policy frameworks seem to influence the development of urban plans. In some cases, cities are ahead of national policy. This paper sheds light on the progress of local adaptation planning in Mediterranean Europe and paves the way for further research in this climate-threatened geographical area.

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1. Introduction

The Mediterranean region is a major climate change hotspot (Tuel & Eltahir, 2020). Observed precipitation and temperature trends in the region show that the climate is changing about twice as fast than global averages (Lionello & Scarascia, 2018; MedECC, 2020), projected changes are also larger in magnitude than those given for other world regions (Cramer et al., 2018; Zittis et al., 2022). The latest IPCC Sixth Assessment Report (IPCC, 2022) points out that Mediterranean countries are likely to be significantly affected by climate change impacts in the future as a result of an increased risk of extreme temperatures, drought, and desertification. Particularly considering the high rate of urbanisation, over 70 % of the population lives in cities (Riccaboni et al., 2020), urban areas need to act on and prepare for the devastating consequences of climate change on people's wellbeing, ecosystems, and infrastructure systems. In terms of policy-making, this requires: (1) understanding the impacts of climate change in cities of Mediterranean Europe (ME), and (2) planning, implementing, and monitoring actions that address these impacts.

In the scientific arena, there has been a significant effort in understanding how urban areas in ME are affected by climate change. For example, Guerreiro et al. (2018) assessed future changes in heatwaves, floods and droughts for 571 European cities, revealing that Southern European cities will experience the largest increase in the number of heatwaves days (as much as 69 %). According to Fischer and Schär (2010), the number of heatwaves days in ME will increase from 2 days per average summer (1961–1990) to 6–24 days in 2021–2050 and is likely to increase to 27–67 days in 2071–2100. Marras et al. (2021) show a decrease in mean precipitation and an increase in extreme precipitation, along with a decrease in mean discharge and runoff. Other studies point out the high vulnerability of coastal Mediterranean cities and port infrastructures to extreme events and sea-level rise (Abadie et al., 2020; Erdas et al., 2015; Marzouk et al., 2021).

ME was also found to be the most susceptible region in Europe to soil degradation and desertification (Fokaides et al., 2016). For example, Ferreira et al. (2022) found that Mediterranean soils are reaching critical limits in their provision of ecosystem services (e.g. loss of infiltration and storage of runoff water, reduced evapotranspiration by loss of vegetation and variations in albedo). This is compounded by the fact that high-quality soils are degraded due to ill-regulated urban expansion (Zambon et al., 2018), and as stated by Fokaides, Kylili, Nicolaou and Ioannou (2016) soil sealing negatively affects the urban heat island effect. Various studies have focused on assessing the impact of climate change on the urban heat island effect in Mediterranean cities (Bevilacqua et al., 2017; Keppas et al., 2021; Mihalakakou et al., 2004; Salvati et al., 2017; Tsoka et al., 2021) and found that the urban heat island will severely intensify for Mediterranean cities as a result of climate variability, with a range of consequences on public health, energy demands to name a few (Cartalis et al., 2001).

Despite this climatic context, however, fewer research efforts have been directed to understand how Mediterranean cities in Europe are preparing for such impacts, i.e., what are the efforts in the area of urban policy and planning. When it comes to adaptation, local public authorities are critical actors in European climate governance, as they perform important functions related to urban design, land use regulation and emergency planning (EEA, 2020).

Urban adaptation planning is widely seen as an instrument to reduce risks from climate impacts (Carter et al., 2015; Guyadeen et al., 2019; Wallace, 2017). Criteria of good planning have to do with the effectiveness of fact base, goals, policies, implementation, monitoring and evaluation, inter-organizational coordination, participation, and plan organization and presentation (European Commission, 2021; Lyles et al., 2018; Olazabal et al., 2019; Reckien et al., 2023). Recent studies demonstrate a rising awareness of the analysis of climate adaptation plans at the urban level, in recognition of the significant role of urban areas to address the challenges of climate change (Geneletti & Zardo, 2016; Pietrapertosa et al., 2019, 2021; Reckien et al., 2018; Salvia, Reckien, et al., 2021). Current scientific trends focus on the comparative assessment of numerous municipalities regarding their efforts in climate adaptation planning (Reckien et al., 2018; Shi et al., 2015) by developing indicators, indicatively based on regression analysis to assess their significance (Fiack et al., 2021; Shi et al., 2015). Local governments have a crucial role to play in the implementation of climate adaptation-related actions (Dale et al., 2020). As stressed in the "European strategy on adaptation to climate change" (European Commission, 2021) is it of utmost importance to rapidly advance local adaptation planning and actions.

However, previous studies have shown that adaptation is lagging behind mitigation in Europe and that there is a North-South divide in terms of climate planning and action at the local level (Reckien et al., 2014, 2018). Furthermore, despite the evidence of the high vulnerability of Mediterranean cities and the significant divide in respect to adaptation policy progress compared to Northern Europe, there is a noticeable lack of systematic knowledge on adaptation planning at the local level in the ME.

To fill this gap, this study analyses the status of local and regional climate adaptation planning in ME, by addressing the following objectives and research questions:

1. *Do national and regional adaptation frameworks influence local adaptation progress in ME?* (RQ1)
2. *What kind of adaptation measures and actions are cities in the ME preparing with?* (RQ2)

Based on a Eurostat sample of 73 cities located in 51 regions across 9 Mediterranean Europe countries, as identified by the Interreg MED cooperation area 2014–2020 (Interreg MED Programme, 2020), this paper investigates to what extent ME cities are prepared for the increasing risks posed by climate change. It explores the local climate adaptation plans (LCAPs) these cities have, identifying climate impacts and planned actions and the level of support in terms of adaptation policy development in the corresponding regions and countries. Urban adaptation planning is framed in the regional and national context, and the presence or absence of regional or national plans is scrutinised, considering any obligations to draw up plans for the lower levels (e.g. national obligation to have regional or municipal plans, or regional obligation to have municipal plans) to understand the role of the national and regional level in urban adaptation planning. This study is a companion of an earlier work analysing planning efforts to mitigate (i.e. reduce the causes of climate change) in cities and regions across ME (Salvia, Olazabal, et al., 2021).

2. Data and methods

The methods adopted in this work are based on a well-established methodology developed within the EURO-LCP Initiative,[1] which periodically researches and analyses urban climate change mitigation and adaptation plans for a sample of 885 cities in 28 European countries (EU27 + UK).

The methodology has been fine-tuned and extended here to incorporate the analysis of climate adaptation plans at the ME region. This study followed four main steps, firstly (Step 1) the sample cities and regions were identified (see details in Section 2.1). In Step 2 (Section 2.2), local, regional and national adaptation planning documents were identified, collected and organised in a common repository. The complete list of the planning document identified is available in the Supplementary materials. In Step 3 (Section 2.3), the contents of the available LCAPs were categorised and analysed in line with common key indicators. Finally, in Step 4 (Section 2.4), the datasets were explored

[1] https://www.lcp-initiative.eu/.

further through graphical and statistical analysis. The latter comprised a binary logistic regression to further assess the role of key variables in driving local adaptation planning in ME.

2.1. Step 1: sample selection

Following the approach used by Salvia, Olazabal, et al. (2021), the selection of the sample began with the identification of the countries and regions in ME, following the boundaries set by the Interreg MED Programme (Interreg MED Programme, 2020). This led to a focus on 9 European countries (Croatia, Cyprus, Malta, France, Greece, Italy, Portugal, Slovenia and Spain) and 51 Mediterranean regions (Fig. 1), which statistically correspond to NUTS (Nomenclature of Territorial Units for Statistics) 2 level (Eurostat, 2021). It is worth highlighting that Cyprus and Malta do not have a subdivision into regions, which means from a statistical point of view the regional level (NUTS2) coincides with the national level (NUTS1) (Salvia, Olazabal, et al., 2021). Whereas for Croatia, the two regions included in the sample, Jadranska (Adriatic) and Kontinentalna (Continental) Croatia, are only regions for statistical purposes but these do not exist in the Croatian administrative system and therefore there are no plans for these Croatian regions. The same for the Slovenian administrative system, here regions do not exist (NUTS2), only division into Eastern Slovenia and Western Slovenia to manage and implement the EU cohesion policy agenda (Ministry of Cohesion and Regional Development, 2023).

Cities in Eurostat's City statistics database, the former Urban Audit database (Bretagnolle et al., 2011; Eurostat, 2015, 2020a), located in these 51 Mediterranean regions were selected. This led to a sample of 73 cities in 51 regions and 9 countries listed in the Supplementary materials.

The Eurostat's City statistics database provides datasets on most aspects of quality of life for a sample of European cities (Bretagnolle et al., 2011). It can be considered a balanced and representative database because it is based on common and transparent hierarchical (minimal population threshold), geographical (spatial dispersion within each country) and administrative (e.g., including national and regional capitals) criteria:

1. Coverage of approximately 20 % of the national population.
2. Inclusion of all capital cities.
3. Inclusion, where possible, of regional capitals.
4. Inclusion of both large (more than 250,000 inhabitants) and medium-sized cities (minimum 50,000 and maximum 250,000 inhabitants).
5. Geographical dispersion of the selected cities within each Member State.

In total, the sample of 51 regions covers a total population of 124.4 million inhabitants in 2019 (Eurostat, 2020b), mostly covered by the population of Italian (48 %), Spanish (20 %) and Greek (9 %) regions. The 73 analysed cities (Supplementary materials) cover a total population of 27,109,575 inhabitants (Eurostat, 2020b). The distribution in classes of the population is represented in Fig. 1.

2.2. Step 2: gathering of adaptation planning documents at the national, regional and city level

Existing and in force climate adaptation plans for each city (Local Climate Adaptation Plans - LCAPs), region (Regional Climate Adaptation Plans - RCAPs) and country (National Adaptation Strategies – NASs and National Adaptation Plans - NAPs) were collected through searches in official websites using the following common strings of keywords: "[city/region/country name] *plan for adaptation to climate change*", "[city/region/country name] *strategy for adaptation to climate change*", "[city/region/country name] *climate plan*", "[city/region/country name] *integrated plan for mitigation and adaptation to climate change*", "[country name] *National Adaptation Strategy*", "[country name] *National Adaptation Plan*", "[country name] *climate plan*". This research was done in each of the nine official national languages involved in the study by native speakers, experts in the domain (the authors).

In addition, the Covenant of Mayors for Climate and Energy database (EU Covenant of Mayors, 2021) was consulted to cross-check the retrieved information and identify the adoption of any Sustainable Energy and Climate Action Plans – SECAPs, which address urban mitigation and adaptation in an integrated matter. The collected documents include publications, strategies and plans with a strong focus on adaptation, but also climate plans containing adaptation targets and measures. The national-level data were also cross-checked with information on the European platform for adaptation knowledge ("European Climate-ADAPT platform," 2021) and updated by the authors.

The online search was undertaken by native analysts in each country and conducted between May 2019 and May 2020 for cities and between May and December 2021 for countries and regions. All collected documents were stored in an internal cloud repository and formed the basis for the content analysis carried out in the next step.

2.3. Step 3: content analysis

The content analysis of all the collected national, regional and city adaptation planning documents was carried out with different levels of detail. For example, the content of the national plans investigated the presence of national obligations for regions and cities in these countries to develop a regional/local adaptation plan. The same was done for regional plans, to check whether regional governments have imposed an obligation on cities to develop an LCAP. Finally, the content analysis of the LCAPs was based on wider research conducted by the entire EURO-LCP Initiative team on 885 urban Audit cities in EU 27 + UK and recently published by Reckien et al. (2023). LCAP data were systematically collected by native analysts in each country through a common questionnaire based on key indicators ([Dataset] Reckien et al., 2022). This was then converted into a rich qualitative and quantitative dataset.[2]

This present study analysed a subset of this database relating to the 73 ME sample cities. The key indicators derived from the content analysis of LCAP through the answers to the questionnaire are organised in two main sections: the first relates to the *impact domains* and aims at surveying which impacts are included in the plans and the second one relates to the *types of adaptation measures* adopted in the different sectors. In particular, the questionnaire considered 10 climate change impact domains and 11 sectors according to Araos et al. (2016) and Revi et al. (2014). In particular, the impact domains include: urban temperature variation; drought and water scarcity; landslides; coastal flooding, sea level rise, and storm surge; forest fire; precipitation variation; inland flooding; storms and wind variation; coastal erosion; and hail. The analysed sectors are: buildings; transport; energy; water; waste; food; environment, greenery and biodiversity; health; social institutions; disaster response systems; tourism for which information on a set of specific adaptation measures was requested during the data collection process.

2.4. Step 4: data analysis

Finally, all collected data were systematically analysed both qualitatively and quantitatively, by using graphical analysis combined with simple statistical methods (i.e. binary logistic regression analysis). The analysis was organised to respond to the two main research questions of the study. On one side (RQ1), factors that impacts local adaptation plans in the ME were analysed, including an analysis of the national and

[2] The complete questionnaire and responses collected and the entire dataset for all cities are accessible in an online repository ([Dataset] Reckien et al., 2022).

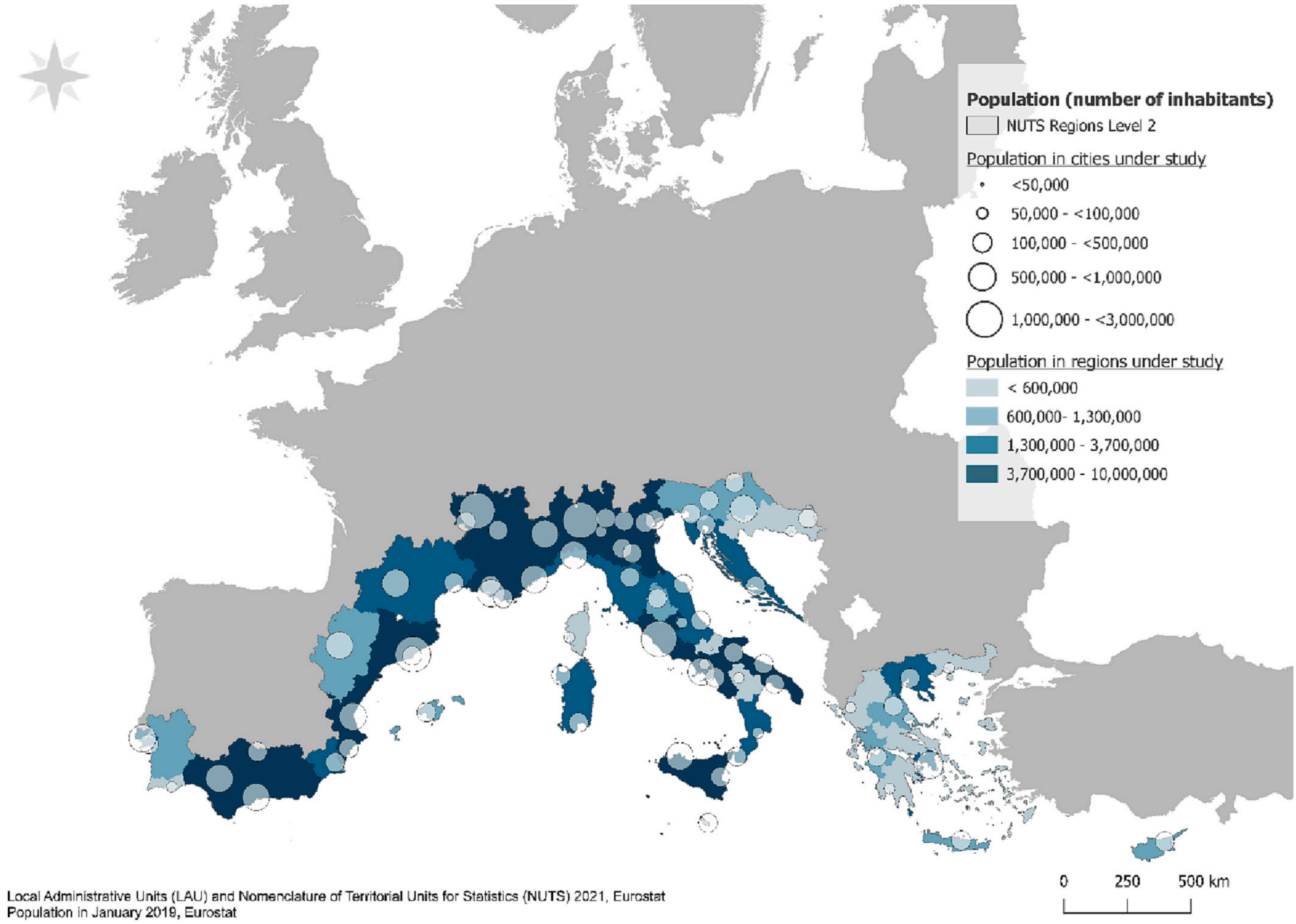

Fig. 1. Sample cities and regions analysed in the ME area (resident population expressed in the number of inhabitants).

regional adaptation frameworks, the timeline of local policy developments and city size. On the other side (RQ2), the contents of LCAPs were investigated based on climate change impact domains identified and specific adaptation measures included in the plans to cope with climate threats are described.

3. Results

In this section, the main findings of the study will be presented. This includes the status of climate adaptation planning at the national and regional levels (Sections 3.1 and 3.2) and the influence of national/regional planning on the definition of adaptation plans at regional/urban level (RQ1) (Sections 3.2 and 3.3). Section 3.4 will present the adaptation framework in cities, illustrating the distribution of plans and the results of the content analysis (RQ2).

3.1. National adaptation planning in ME

Since the first European adaptation strategy of 2013 (Europen Commission, 2013), Europe has underlined the need for a commitment of Member States in adaptation policies. With the most recent strategy adopted in February 2021 (European Commission, 2021) and with the subsequent climate law (European Union, 2021) the importance of national adaptation strategies and plans is reaffirmed, and States are urged to make them effective and develop them further. The member states have embraced the solicitation of Europe and have adopted a series of national adaptation strategies (NASs) and national adaptation plans (NAPs) which represent the programmatic and executive tools to face the consequences of climate change.

Although the distinction between NAS and NAP is not well established and each state is left free to define the legal status and the extent of action of the documents (EEA, 2023), the NAS can broadly be defined as a document that provides overall and often long-term strategies that differs from the NAP which, instead, is a policy document that allows moving from planning to implementation (EEA, 2013). A NAS usually analyses the state of scientific knowledge on the impacts and vulnerability of climate change for key environmental and socio-economic sectors and presents a set of proposals and criteria for action to address the consequences of climate change and reduce its impacts. A NAP is the implementation tool of the NAS, a programmatic document aimed at providing the context and resources for implementing the adaptation measures identified in the NAS. Existing National NAS and NAP in the 9 ME countries are reported in Table 1.

Table 1 shows the status of climate change adaptation planning in ME countries where some countries have developed strategic frameworks for national adaptation and other countries have also produced or are working on detailed national adaptation plans. Except for Spain, all the considered ME countries have a NAS in force. In contrast, only five out of nine ME countries have adopted a plan (NAP), while in the remaining countries, NAPs are under development. For example, in Italy, the National Plan for Adaptation to Climate Change was drafted in 2018 and only recently (December 2022) it was updated with a strong political engagement to approve it by the end of 2023. The analysis of the policies undertaken by the ME countries shows that, albeit with various delays, 4 other countries are close to approving a NAP or are developing one. It is thus expected to have an action plan (NAP) in 89 %

Table 1
National Adaptation Strategies (NAS) and National Adaptation Plans (NAP) of the ME countries (mainly based on ("European Climate-ADAPT platform," 2021)).

Country	National Adaptation Strategies (Year of adoption)	National Adaptation Plans (Year of adoption)	National obligation to develop adaptation plan (Level)
Croatia (HR)	Yes (2020) (Croatian Parliament, 2020)	Being developed	No
Cyprus (CY)	Yes (2017) (Department of agriculture rural development and environment, 2017)	Yes (2020) (Department of agriculture rural development and environment, 2020)	No
France (FR)	Yes (2007) (Onerc, 2007)	Yes (2018) (Ministère de la Transition Ecologique et Solidaire, 2018)	Yes (regional and municipal)
Greece (EL)	Yes (2016) (Ministry of Environment and Energy, 2016)	Being developed	Yes (regional)
Italy (IT)	Yes (2014) (Italian Ministry for the Environment Land and Sea, 2014)	Waiting for approval (Ministry of the Environment and Energy Security, 2022)	No
Malta (MT)	Yes (2012) (Ministry for Resources and Rural Affairs - Government of Malta, 2012)	No	No
Portugal (PT)	Yes (2015) (Portuguese Council of Ministers, 2015)	Yes (2019) (Portuguese Council of Ministers, 2019)	Yes (regional)
Slovenia (SI)	Yes (2021) (National Assembly, 2021)	Being developed	No obligation, but recommended (municipal)
Spain (ES)	Not in force. Previous (2007–2020) (Ministry for the Ecological Transition and the Demographic Challenge, 2007)	Yes (2021) (Ministry of the Environment, 2021)	No

of ME countries in the next few years.

In Croatia, Cyprus, Italy, Malta, Portugal, and Spain there are no national legal obligations to draw up urban adaptation plans (see Table 1, last column), while in France there is a national law that defines and regulates climate change plans and actions for regions and cities. The French national law makes it compulsory to have a plan called the SRADDET (Regional plan for planning, sustainable development and territorial equality); including older plans called SRCAE (Regional Climate, Air and Energy Plan). The SRADDET/SRCAE are mandatory, and they must contain among other subjects medium- and long-term objectives on adaptation to climate change (articles R. 4251-4 to R. 4251-7 of the General Code of Local Authorities). In Slovenia, for example, the Resolution on the Long-Term Climate Strategy of Slovenia until 2050 (Ministry of the Environment and Spatial Planning, 2021) provides guidelines for local adaptation planning and recommends that local authorities draw up an adaptation plan, but there is no legal obligation to do so. In Greece, the NAS requires regions but not cities to have an adaptation plan. According to the Portuguese National Strategy for Adaptation to Climate Change 2020 - ENAAC 2020, adopted in July 2015, regions must have an adaptation plan. The Portuguese NAS also establishes guidelines for drafting subnational (municipal and inter-municipal) strategies and plans (European Commission, 2018). More recently, without a legal framework, the Portuguese Action Programme for Adaptation to Climate Change established as a target that by 2030 all Portuguese municipalities should have an adaptation plan (municipal, inter-municipal or regional). Lastly, for example, in Spain, the National Plan for Climate Adaptation recognizes that Mediterranean cities are suffering more intense climate impacts (Ministry of the Environment, 2021). Taking this into account and considering that cities are particularly vulnerable, the Plan sets specific actions by coordinating and reinforcing the connection with the Spanish Urban Agenda. Additionally, it proposes to advance a common framework of indicators to monitor urban action (including climate adaptation). It recommends that all these plans and actions are coordinated by the Autonomous Communities and the municipalities through interdepartmental and intersectoral commissions. It is worth noting that no additional resources are planned at this time. However, the Plan integrates initiatives for climate adaptation into urban planning, and the construction sector, and for enhancing citizens' participation in these processes.

3.2. Regional adaptation context

Overall, at the regional level, 30 Regional climate adaptation plans – RCAP, were identified (59 % of the 51 screened regions). Excluding Croatia, Cyprus, Malta and Slovenia, which do not have a regional legal entity from an administrative point of view, this percentage rises to 67 %. Regional plans are fully adopted in France (5; 100 %), Greece (13; 100 %), Portugal (3; 100 %), and Spain (6; 100 %). In France, Greece and Portugal, there is a nationally set obligation for regions to have an RCAP. However, Spain, despite having no obligations, maintains a very high incidence of RCAP, while in Italy only 17 % of regions with an RCAP (only 3 regions out of 18) lag far behind other ME countries. The complete list of the RCAPs is reported in the Supplementary materials. The least active regions are those in ME countries where there is no national legislative obligation to draw up RCAPs (24 regions out of 45). Only 38 % of these regions have an RCAP against 100 % of the regions in ME countries where RCAPs are mandatory. However, a deeper analysis of the regional context for those ME countries with regions with legal entities intermediate between the national and municipal level (France, Greece, Italy, Portugal and Spain, 45 regions in total) shows that (see Fig. 2):

- the presence of a NAS positively influences regional adaptation planning. In countries with a NAS, 62 % of the regions have an RCAP. As already mentioned, the only country without a NAS in force is Spain, but the presence of the NAP, and a previous (2007–2020) NAS, also have a positive effect on regional plans (i.e., all 6 regions considered have an RCAP);
- the influence of the presence of a NAP is stronger, in this case, the data show that 100 % of the regions in ME countries with NAP have the RCAP, while in the countries without NAP (Italy only) only 48 % of the regions have an RCAP.

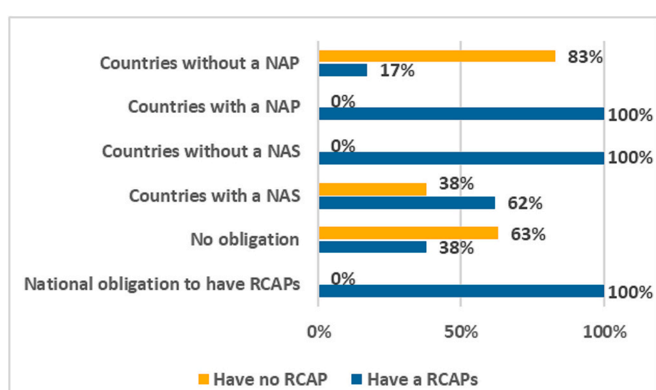

Fig. 2. Influence of national planning on the definition of RCAP (calculation made excluding countries without regions Croatia, Cyprus, Malta and Slovenia).

3.3. Analysis of factors affecting local adaptation plan development in ME

None of the ME regions obliges municipalities to adopt an adaptation plan, but how much is urban adaptation planning influenced by the context of regional and national adaptation planning? The national obligation on municipal plans in our sample, as already mentioned, is in force only in France, and has a strong influence, 90 % of cities have an adaptation plan (9 out of 10), while only 21 % of cities located in countries without a national obligation have a LCAP. By relating the national and regional legislative framework to the preparedness of the cities, our results show that (see Fig. 3):

- the presence of a NAS or a NAP is not a driver for the definition of LCAP: in countries where a NAP or NAS or both exist only 30 % of cities have an LCAP;
- the presence of a NAS is not a driver for the definition of LCAP: in countries with NAS, only 29 % of cities have LCAP;
- while the situation regarding the NAP is perfectly balanced, the presence of a NAP does not influence the definition of urban plans: the number of cities in countries with NAP without a plan and with a plan is the same (16; 67 %), however in countries without NAP, 71 % of cities do not have an LCAP;
- RCAP is not an indicator for LCAP: only 41 % of LCAP are located in regions with RCAP, while 71 % of cities with an adaptation plan are located in regions without RCAP.

If we analyse the urban population of our cities sample by city size, we find that, it is mainly composed of small and medium-sized cities with a population below 0.2 million inhabitants (representing 50 % of the cities in the sample). Most of the small and medium-sized cities are in Italy (23 %), and to a less degree in Greece (10 %). As illustrated in Fig. 4, the number of cities with an adaptation plan increases as their population increases suggesting a potential positive correlation between the probability to have an adaptation plan and the city size.[3]

To further assess whether the city size as well as the national obligation to have an adaptation plan at the local or regional level play a role in the potential for a city to have an adaptation plan, a binary logistic regression was carried out. The dependent variable of whether a city has a plan or not was regressed on two independent variables, the logarithm of "City population" and "National obligation for local or regional adaptation plan". A positive correlation was observed between the probability to have an adaptation plan and the city size (i.e. point-biserial correlation coefficient with the logarithm of the population equal to 0.33, significantly positive with 99 % confidence) as well as the variable of a regional or national obligation for LCAP development (i.e. point-biserial correlation coefficient with the logarithm of the population equal to −1.8142, significantly positive with 95 % confidence) for cities in the ME region. This result holds even when considering only cities outside France, i.e. only cities with no national obligation to have an adaptation plan. This conclusion is in line with what was found, in the literature, in other geographical contexts (Reckien et al., 2014), and highlights once again this tendency.

This suggests that both population size and obligation to develop adaptation plans (as it happens for cities in France and regions in Greece) play a positive role in driving local adaptation planning in the ME region. Notably, except for Rome, all capital cities in the sample (Zagreb, Lisbon, Ljubljana, Athens and Nicosia) have an LCAP whereas, the capital cities of Spain (Madrid) and France (Paris) are not part of the considered sample as they are outside the Mediterranean areas considered in this study.

[3] Point-biserial correlation coefficient of the binary variable "have an adaptation plan" with the logarithm of the population is equal to 0.33, significantly positive with 99 % confidence.

3.4. Climate impacts and planned adaptation actions in cities

3.4.1. LCAPs in ME: where and when

Among the 73 ME cities in the sample, only 22 (30 %) had a Local Climate Adaptation Plan (LCAP). As previously shown, the majority of those that had an LCAP are cities in France (9 plans out of 10 French cities in the ME sample; 90 %), the only country in the sample that requires cities to have an LCAP, followed by Spain (4 out of 10; 40 %), Greece (2 out of 9; 22 %), Italy (2 out of 31; 2 %), Slovenia (2 out of 2; 100 %), Portugal (1 out of 3; 33 %), Croatia (1 out of 5; 20 %) and Cyprus (1 out of 1; 100 %). Most ME cities without LCAPs are in Italy, which has the lowest rate of development of local adaptation policy across the sample. There are some peculiarities or specific cases that are worth noting. For example, in the case of Malta, represented in the sample by the city of Valletta, policies and plans are not developed at the urban scale but on a smaller scale (as there are several localities with autonomous powers on climate policies). Therefore, as per the criteria used in this study to select adaptation planning documents (i.e., scale not smaller than municipal administration) no Maltese LCAPs have been considered. The full list of planning documents (inc. strategies and action plans) can be found in the Supplementary material.

The identified 22 LCAPs were adopted after 2012, except for the LCAP of Maribor (Slovenia) dating back to 2008. Most of the current plans are recently published, either after 2019 (36 %) or after 2017 (64 %). Only 7 plans are revised versions of a pre-existing plan. These are Grenoble, Saint-Etienne, Ajaccio and Nice, in France (their previous plans date back to 2005, 2010, 2012 and 2013 respectively), Zaragoza and Barcelona in Spain (their previous plans date back to 2009 and 2015 respectively) and Ljubljana in Slovenia (its previous plan dates 2007).

3.4.2. Climate impact domains addressed by LCAPs

All LCAPs include an analysis of the climate impacts faced by each city, although more or less comprehensive. Across the 22 LCAPs, almost all municipalities consider 'Urban temperature variation' (21 plans, 95 %) and 'Precipitation variation' (20 plans, 91 %) as the most important climate impacts that need to be addressed at the urban level (see Fig. 5). 'Drought' and 'water scarcity' are included in 68 % of the LCAPs analysed (15 out of 22), and 'Inland flooding' and 'Landslides' were considered by 59 % (13 LCAPs out of 22) of the cities. 'Coastal flooding', 'sea-level rise', and 'storm surge' are impacts that typically afflict low-elevation coastal zone (that is, those areas located from 1 m to 20 m of altitude above mean sea level) and are thus included in the plans of 10 coastal cities (Cyprus, Marseille, Aix en Provence, Montpellier, Nice, Ajaccio, Ancona, Lisbon, Valencia and Barcelona), representing 45 % of the analysed sample. Far fewer cities considered impacts such as 'storms' and 'wind variation', which were included in 27 % (6 out of 22) of the LCAPs, while 'forest fire', 'coastal erosion' and 'hail' overall were included in 24 % (5 out of 22) of the plans.

3.4.3. Sectors addressed by adaptation actions in the analysed LCAPs

11 sectors were pre-considered as part of the designed LCAP questionnaire (see Table 2, Fig. 6). However, specific measures were collected as they emerged from the analysis of the content of plans (see Table 2). Results show that ME cities more often plan adaptation measures in sectors related to the environment, greenery and biodiversity (included in 19 out of 22 plans; 86 %); water (18 plans; 82 %), health (17 plans; 77 %); buildings (16 plans; 73 %) and transportation (15 plans; 68 %) (see Fig. 6). The energy sector is the least considered (8 plans; 36 %), followed by social Institutions (11 plans; 50 %), and tourism (11 plans; 50 %).

Table 2 provides the distribution of the type of measures per sector in the 22 LCAPs identified in the ME region.

Most of the measures surveyed (see Table 2) fall within the Environment, greenery and biodiversity sector, with a total of 43 adaptation measures out of 247, the Food sector (overall 35 measures identified, Water and Transport (32 and 31 measures respectively) and the

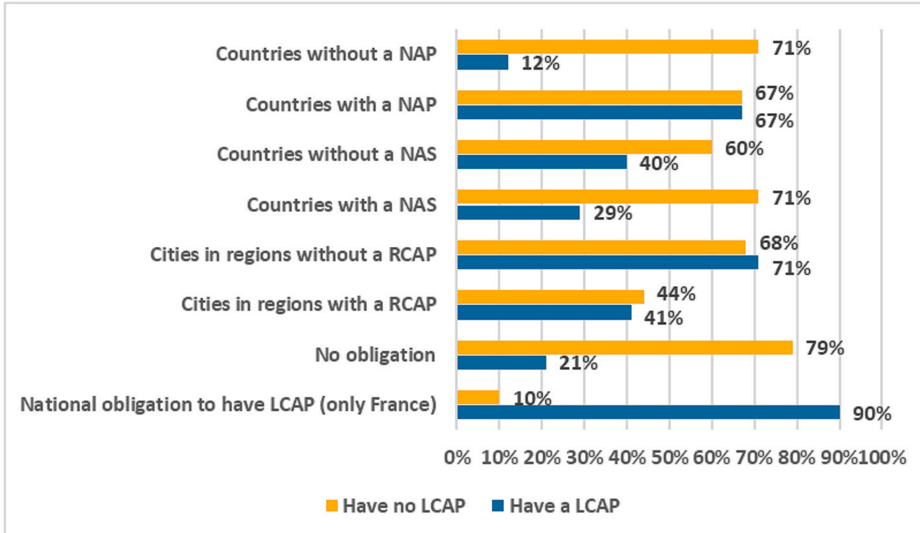

Fig. 3. The role of regional and national planning on the definition of LCAP.

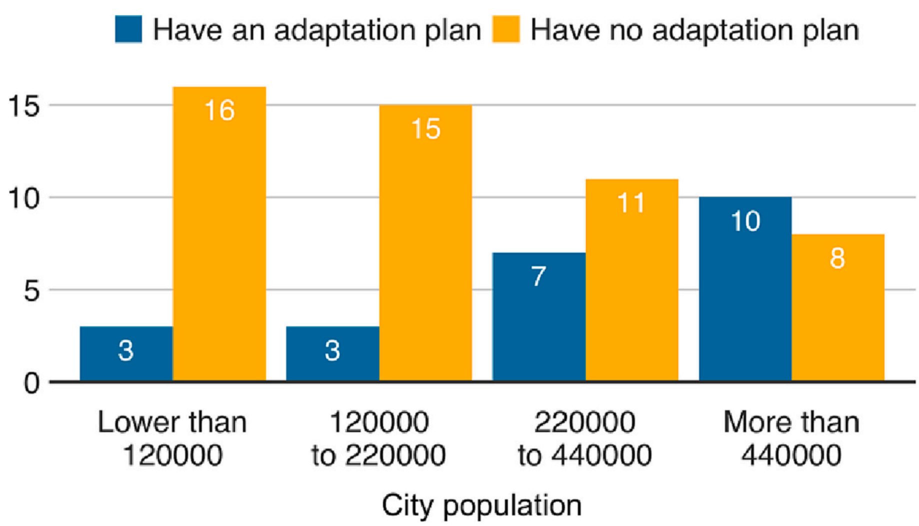

Fig. 4. The role of city size on local adaptation planning development in the ME.

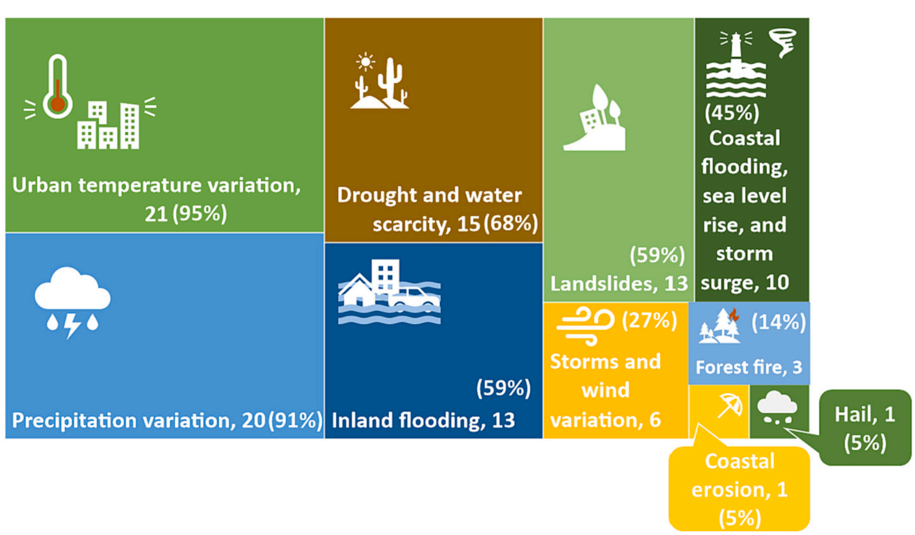

Fig. 5. Impact domains mentioned by the 22 LCAPs (a larger area corresponds to a greater number of LCAPs considering such impacts).

Table 2
Sectors and specific adaptation measures included in the LCAPs.

Sectors	Type of measures	N and % of adaptation measures in LCAPs
Building	Changing/improving or enforcing building codes	13 (5.3 %)
	Increasing/improving insulation	6 (2.4 %)
	Low-density development	1 (0.4 %)
	Green Roofs creation	1 (0.4 %)
	Walls, shading systems, cooling construction material	1 (0.4 %)
	Brownfields/infill development	1 (0.4 %)
	Spatial planning for land use based on zone areas for flood management	2 (0.8 %)
	Urban retrofit with Bioclimatic building design	1 (0.4 %)
	Mixed-use, integrate climate change in Master Plan.	1 (0.4 %)
	TOT measures	*27 (10.9 %)*
Transport	Public transport/Transit-oriented development in general	13 (5.3 %)
	Bicycle-oriented development	10 (4 %)
	Pedestrian-oriented development (e.g., shading of pedestrian areas, etc.)	6 (2.4 %)
	Better information to redirect car traffic in case of flooding	1 (0.4 %)
	Underground routes.	1 (0.4 %)
	TOT measures	*31 (12.6 %)*
Energy	Climate change risk analysis of existing energy infrastructure	2 (0.8 %)
	Solar roofs to reduce heat; increased albedo for buildings (green roofs)	4 (1.6 %)
	Increased albedo for buildings (using light colours and green roofs)	1 (0.4 %)
	Bio-climatic urban design (e.g., use of sustainable construction material).	2 (0.8 %)
	TOT measures	*9 (3.6 %)*
Water Infrastructure	Enlargement/improvement of drainage systems	14 (5.7 %)
	Conservation: Water metering, greywater use, water restrictions/rationing	15 (6.1 %)
	Blue corridors creation (i.e., revival of water-stream)	2 (0.8 %)
	Fountain's installation.	1 (0.4 %)
	TOT measures	*32 (13 %)*
Waste	Yes	10 (4 %)
	TOT measures	*10 (4 %)*
Food	Support for local farmers	13 (5.3 %)
	Conservation of agricultural or forestry lands	10 (4 %)
	Support of organic food	11 (4.5 %)
	Urban cultivation site on schools & neighbourhoods.	1 (0.4 %)
	TOT measures	*35 (14.2 %)*
Health	Determinants of health: clean air, safe drinking water, food and shelter security	14 (5.7 %)
	Provision of care systems: health care centres, hospitals, warning systems, etc.	5 (2 %)
	Regular maintenance and cleaning of sewage	1 (0.4 %)
	Determinant health: reduce high temperatures.	1 (0.4 %)
	TOT measures	21 *(8.5 %)*
Environment, Greenery and Biodiversity	Green spaces: Increase in quality/quantity/protection of street trees, parks, green roofs, green backyards, green belts	18 (7.3 %)
	Blue/green spaces: Increase in quality/quantity/protection of flood marshes/flood plains/salt marshes: increase in quality or quantity	10 (4 %)
	Blue spaces: Increase in quality/quantity/protection of watersheds, lakes, streams	9 (3.6 %)
	Brown spaces: Increase in quality/protection of soils and soil functions.	6 (2.4 %)
	TOT measures	*43 (17.4 %)*
Social Institutions	Schools, kindergartens, and other educational facilities	10 (4 %)
	Sports facilities, public swimming pools	2 (0.8 %)
	Social facilities, e.g., shelters and others.	3 (1.2 %)
	TOT measures	*15 (6.1 %)*
Disaster Response Systems	Yes	13 (5.3 %)
	TOT measures	*13 (5.3 %)*
Tourism	Yes	11 (4.5 %)
	TOT measures	*11 (4.5 %)*
Total number of measures		247

Buildings and Health sector (27 and 21 measures)). Almost two-thirds of the plans include measures in the Transport, Water and Building sectors. Instead, sectors like Social Institutions (schools, sports and social facilities), Disaster Response systems, Tourism, Energy and Waste were identified in approximately half or less of the plans reviewed.

3.4.4. *Detailed distribution of adaptation measures in the LCAPs*

Taking a closer look at the types of measures (see Table 2), our results show a high intention of municipalities to plan and take actions to increase the quality, quantity and protection of green spaces (18 measures) such as street trees and other green environments that reduce air and surface temperatures, blue/green and blue spaces (19 measures) (e.g., artificial lakes, reservoirs, and retention ponds) and to a lesser extent soil and soil functions (6 measures).

More than 60 % of the plans across the sample include measures on grey infrastructures, such as enlargement/improvement of drainage systems (14 measures). 15 measures have been counted for water conservation, such as water metering, greywater use, water restrictions/rationing, and underlining a common vulnerability and priority area across the cities. Similarly, in the food sector measures such as support for local farmers (13), conservation of agricultural or forestry lands (10) and support of organic food (11) were found in almost half of the plans analysed. In transport the most frequently reported measures are related to public transport (13 measures) and bicycle-oriented development (10). The building sector is the one in which a higher level of diversity was reported in terms of measures. Specifically, changing/improving or enforcing building codes (13 measures) and improving insulation (6 measures) are the most common measures in this sector. Finally, in the health sector, most of the identified measures concern the achievement of clean air, safe drinking water, food, and shelter security (14 measures).

4. Discussion

This study aimed at analysing the state of the art of local and regional adaptation planning in the ME, investigating (i) whether the regional

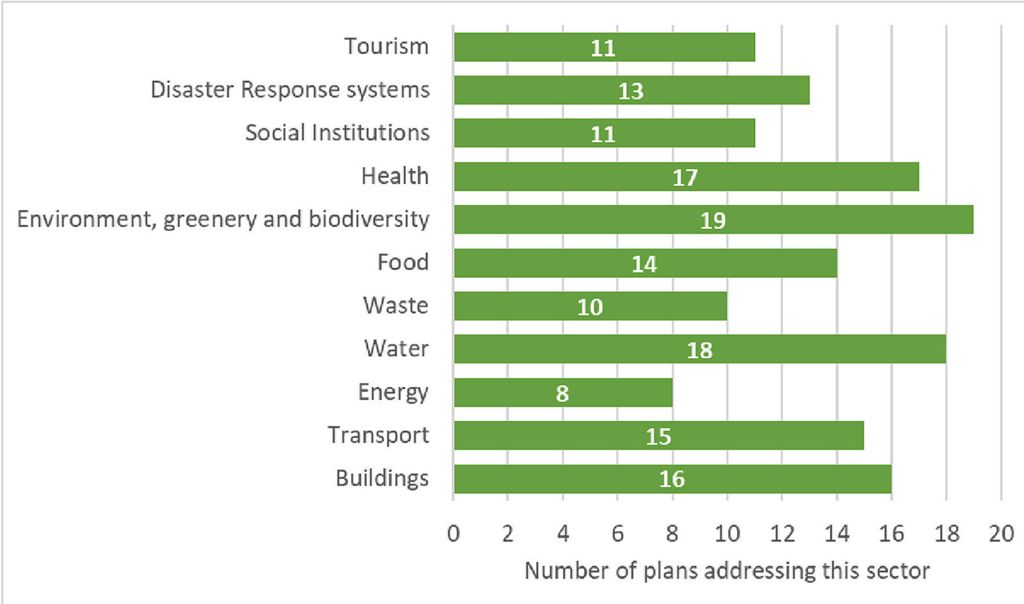

Fig. 6. Distribution and predominance of sectors addressed by LCAPs in ME.

and/or national adaptation frameworks positively influence lower administrative levels in adopting adaptation plans; (ii) what kind of impacts cities consider in their plans and what actions are taken to address them. In Section 4.1, we discuss the results for both research questions. In Section 4.2, we compare the conclusions reached in our study with the main results available in the scientific literature, and possible areas that need to be further investigated in future studies are presented in Section 4.3.

4.1. Are ME cities preparing for the most pressing climate impacts and what are the drivers of progress?

Policy progress is uneven, i.e. concentrated on certain countries and larger cities. Of the 73 cities in the sample, 22 (30 %) have LCAP(s). This is slightly higher than the number of urban adaptation plans in Europe as a whole (Reckien et al., 2018), which is about 26 %. With a projected elevated risk of climate impacts, such as extreme temperatures and drought (IPCC, 2022, Ch.13), many cities of ME are potentially falling short of their adaptation need. Particularly Italy, the country with the highest number of cities in our ME sample (31 out of 73, 42.5 %), i.e., with the highest vulnerability in terms of urban population and assets exposed, has the lowest number of LCAPs in the sample (only 2 out of 31). Out of the 22 cities with a climate adaptation plan, nine cities (41 %) are in France, i.e., the country where it is compulsory to develop local adaptation policies (with 9 cities out of 10 with LCAP). While all countries in the sample have national adaptation strategies or plans in place or to be published soon, except for France, none of them makes it compulsory to develop LCAPs. Hence, 13 cities (59 %) are located outside of France and developed local adaptation plans without the legal requirement to do so.

The national and regional frameworks for the analysed ME countries and regions are quite diverse and can have a great influence on city strategies either through direct regulation, by facilitating coordination between actors or by increasing data availability (Heidrich et al., 2016). To understand the local climate adaptation action of ME cities it is important to place them in their national or regional context. Such a multi-scale approach has the potential to explain the current situation regarding the state of urban climate adaptation planning. However, we found contrasted experiences in the different countries. The significant difference between NAS and NAPs, in force in 89 % and 44 % of ME countries respectively, reflects the tendency of countries to move from the initial stage of recognising the seriousness of the negative impact of climate change to a stage of defining concrete actions.

Concerning regions, for example, all regions in Greece (13) have an adaptation plan in place, because it is set as a legal requirement by the national policy. In Spain, despite there being no national obligation to develop regional plans 100 % of Spanish regions developed an RCAP. In Italy, where only the NAS exists and there are no obligations either for the regions or for the cities to develop adaptation plans, only 3 out of 18 regions have developed adaptation plans. In addition, from the results, a national obligation to develop LCAPs is a stronger driver of the emergence of local adaptation plans in the ME (90 % of cities have LCAP) than a regional adaptation policy framework (41 % with LCAP). Assumedly, the progress on local or regional adaptation planning in ME is more related to exiting governance structures in the country (for example, competencies of regional authorities) than to the adoption of NAS or NAPs.

Our study shows that city size still seems to play an important role in the development of LCAPs. This finding resonates with earlier studies in European cities (Reckien et al., 2014), that, over a larger sample of cities (200) concurred on the influence of city size. The reason for this beyond the connection to international/transnational city networks (Heikkinen et al., 2020), is still underexplored, although we suggest that the lack of access of smaller cities to financial resources and technical support might be one important driver.

The state of planning in the ME is quite recent. With exception of the city of Maribor with a LCAP adopted in 2008, all LCAPs in ME cities have been adopted after 2012 and the majority of them (63 %) after 2016, i.e., after the adoption of the Paris Agreement in 2015. This is an epoch where the progress on adaptation policy action at the subnational level seems to emerge globally (Castán Broto & Westman, 2020; Olazabal & Ruiz De Gopegui, 2021).

In terms of the type of adaptation measures, proposals for nature-based solutions were found in the majority of adaptation plans. This may suggest an awareness of the adaptation provision potential of measures aimed at enhancing key ecosystem services (e.g., stormwater and flood management, microclimate regulation). Nature-based solutions, such as urban nature restoration and greening interventions, are praised for their multiple benefits through the reduction of urban risks (Goodwin et al., 2023; IPCC, 2022) and relatively low costs (Fernandez de Osso Fuentes et al., 2023).

However, given that many of the cities in ME regularly experience water scarcity (Joint Research Centre, 2018), whose severity is expected to intensify in coming decades (Vicente-Serrano et al., 2014), adaptation and mitigation of heat extremes and urban flooding by way of renaturation can result in a challenge (Gill et al., 2013). Beyond water availability, the position, type and size of natural infrastructures are crucial elements to achieving sufficient impacts on urban risks (Tardieu et al., 2021). For instance, it has been demonstrated that in Mediterranean latitudes, larger green surfaces with higher edge density and forests provide a greater cooling effect than several smaller surfaces with the same sum of the surface (Nastran et al., 2019). Given that most Mediterranean cities are old cities with dense neighbourhoods and sealed surfaces (EEA, 2012, 2016), space (and probably land prices) will also represent a challenge for an efficient implementation of nature-based solutions.

4.2. Is this picture different from local adaptation planning progress worldwide?

A question remains regarding whether the findings of our study on local adaptation policy progress in the ME are aligned with similar studies in the literature. The findings regarding the sectors addressed and the measures planned resonate with other works. For example, the water management and transport sector often emerge as important action arenas (see e.g. (Kalbarczyk & Kalbarczyk, 2020) and (Singh et al., 2021)). Also, building codes, green infrastructures and conservation strategies to preserve biodiversity are frequently reported in the local adaptation plans (see e.g. (Stults & Woodruff, 2017)).

In terms of the factors influencing the existence of LCAPs, the results of this study also concur with previous studies. Particularly, Reckien et al. (2015) investigating 200 large and medium-sized cities in eleven European countries found that city population is one of the drivers towards the development of mitigation and adaptation plans and reports that for every ten thousand inhabitants, the likelihood of a city having an adaptation plan rises by 1 %. Araos et al. (2016) analysing 401 local governments in urban areas and tracking climate change adaptation policies found that extensive adaptors (cities with more than 17 adaptation initiatives), are mainly large cities located in high-income countries.

Other studies investigating only large cities found that a high share of them (compared to studies with more diverse samples in terms of city size) has adaptation plans. For example, Olazabal and Ruiz De Gopegui (2021) found that among the 136 largest port cities worldwide 59 have an adaptation plan and Fiack et al. (2021) studying the 100 largest US cities found that 45 have climate adoption plans. The analysis of Reckien et al. (2018), which collected and analysed information on local climate plans (both for mitigation and adaptation) in 885 cities in the European Union (a larger sample including the cities sampled for this study), found that the population of the city constitutes a factor influencing the adoption of local mitigation and/or adaptation plans, while the existence of national obligation for cities to develop a local climate plan has a significant effect on the likelihood of a city developing one, specifically the national obligation makes it almost twice as likely for a city to have a mitigation plan and five times more likely to have an adaptation plan. Similar results are also presented by Heidrich et al. (2016) and Lee et al. (2020) that investigated the trade-offs between urban climate change mitigation and adaptation policies and found a positive relationship between the existence of a national climate adaptation mandate for cities and the local climate adaptation policy. Lee et al. (2020) argue that cities with a mandate have a 65 % probability to have a local adaptation policy, while in counties without a mandate, cities will have a corresponding probability of 38 %. However, the relevance of these findings and their validity in time are still questionable since for example, Heikkinen et al. (2020), investigated the association between international city network membership and progress in adaptation planning in 377 cities, arguing that cities that are required to plan for adaptation are likely to be more advanced in their adaptation planning, and that larger cities may have better capacities for adaptation than smaller ones, included both variables in their analysis but found mixed results on the significance when using different models. The state of local adaptation planning is evolving quickly and studies like the one presented here need to be updated regularly to understand the dynamics and driving forces of policy development as well as the impacts of these policies.

4.3. Possible areas for future research

Future investigations should focus on the analysis of the effectiveness of plans. For example, research is needed to understand how adaptation measures are considering and addressing urban density and water availability in the case of ME cities. Realizing that many cities in our sample are planning for nature-based solutions despite being dense, old medieval cities located in a water-scarce environment (EEA, 2012, 2016; Joint Research Centre, 2018), the adopted strategies might be bound to create more problems than they can solve. It can for example require unsustainable water levels for ME cities or involve a very high cost for limited efficiency. Indeed, it has been recently demonstrated that for some scenarios of climate change, hybrid approaches (mixing green and grey solutions) would provide a greater net benefit for high-intensity events, particularly in the case of urban stormwater management (Chen et al., 2021). This kind of analysis could require spatial modelling exercise to compute adaptation cost-effectiveness of urban renaturation in a context of constrained space and water by using existing spatially explicit models e.g. Urban InVEST (Hamel et al., 2021) compared with other measures or mixed strategies. From a conceptual point of view, in an era of compound crises (Westman et al., 2022), understanding how adaptation strategies address different nexus, e.g. water-energy-land nexus (Cremades et al., 2021) or the climate-biodiversity-society nexus (Goodwin et al., 2023), is critical and necessary to frame effectiveness in urban adaptation.

5. Conclusion

This study analysed the status of urban climate change adaptation efforts in Mediterranean Europe (ME). It investigated the extent to which cities and towns across ME are preparing to address the potential future impacts of global climate change by planning and implementing a set of actions.

Our results show that only 30 % of the cities in the ME sample have adopted an LCAP and that local adaptation planning is mainly driven by population size (the larger the number of inhabitants, the more likely the city is to have a plan) and national legal requirements to develop LCAPs (as in the case of France). This aligns with existing literature and the state-of-the-art globally as discussed in this paper. Our study revealed that the most common concerns across ME cities are the variation in urban temperature and rainfall. Drought and water scarcity are also quite common impacts addressed in adaptation plans, followed by floods and landslides. To improve the resilience and adaptation capacity of the ME municipalities, local administrators primarily rely on green measures based on a nature-based approach, water conservation (water metering, greywater use, water restrictions/rationing) and water infrastructure (enlargement/improvement of drainage systems). Also, health, transport and the building sector (including codes and spatial planning) were considerably addressed across plans. Although the types of measures and sectors addressed seem to be aligned with the specific ME climate change challenge, the state of planning in the ME is quite recent and still insufficient to address the most pressing climate impacts, especially in countries such as Italy, where only 6 % (2 out of 31) of the cities in our sample have developed LCAPs.

The quality of the plans, processes of implementation and outcomes of adaptation programs need to be studied in more detail to identify the factors that lead to successful and effective adaptation in the ME. Understanding how Mediterranean cities plan to manage climatic risks and monitoring this perspective over the years will enable better-informed decision-making and the allocation of related resources mainly through the identification of action gaps.

Nomenclature

ME	Mediterranean Europe
LCAP	Local Climate Adaptation Plan
RCAP	Regional Climate Adaptation Plan
NAS	National Adaptation Strategy
NAP	National Adaptation Plan

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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.

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Appendix A. Supplementary data

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