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Ecosystem-based adaptation in cities: An analysis of European urban climate adaptation plans

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ABSTRACT

Ecosystem-based adaptation (EbA) measures have been increasingly promoted in the literature, as well as in policies and practices, for their environmental and socio-economic co-benefits. The recent scientific literature has shown a growing interest to assess climate adaptation plans at the urban level, in recognition of the important role played by urban areas in addressing climate change challenges. However, little information is available on the combination of these two issues, i.e., the actual inclusion of EbA measures in climate adaptation plans at the urban level. This paper addresses this gap by developing a framework to analyze the treatment of EbA in urban level climate planning, and apply it to a sample of climate adaptation plans in Europe. The framework consists of a classification of EbA measures, and a scoring system to evaluate how well they are reflected in different components of the plans. The results suggest that there is in general good awareness in plans of EbA measures, and of their potential role in addressing climate change challenges. However, their treatment in climate adaptation plans at the urban level often lacks sufficient baseline information, as well as convincing implementation actions. The paper concludes by offering recommendations to improve future practice, in terms of enhancing the baseline information to improve the proposal and design of EbA measures, improving the treatment of co-benefits associated to EbA measures, and strengthening coordination with other planning tools. Possible future development of this works include the integration of the proposed EbA classification, and the analysis of a larger sample of territorial plans.

1. Introduction

Climate change adaptation includes actions undertaken in natural or human systems in response to actual or expected climatic stimuli or their effects, in order to reduce harm or exploits benefits (IPCC, 2007). Although historically adaptation to climate change has received less attention than mitigation (Füssel, 2007), there has been a recent surge of interest in adaptation interventions, which are already a necessity in many contexts, particularly until greenhouse gases emissions will not be stabilized (Picketts et al., 2013).

Adaptation to climate change may be attained in different ways. One way that is attracting increasing attention is through ecosystem-based approaches. Ecosystem-based adaptation (EbA) is defined as the use of biodiversity and ecosystem services to help people to adapt to the adverse effects of climate change (CBD, 2008). The concept of EbA was first introduced in the international policy arena by the United Nations Framework Convention on Climate Change in 2008, and has been widely advocated by environmental organizations since then (Colls and Ash, 2009; TNC, 2009). EbA approaches include management, conservation and restoration of ecosystems that deliver services that can help to reduce climate change exposures (Munang et al., 2013a). For example, restoring mangrove forest can contribute to dissipate the energy of storm surges, buffering human communities from floods and erosion (Erwin, 2009). Protecting groundwater recharge areas and floodplain can help to secure water resources and cope with droughts (TNC, 2009). Enhancing green infrastructures in urban areas can reduce the heat island effect, and the associated health risks (Lafortezza et al., 2013).

As opposed to more traditional infrastructure-based approaches (e.g., levees, sea walls, irrigation systems), EbA offers the advantage of promoting "no regrets" interventions, and potentially delivering multiple economic, social and environmental co-benefits

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that go beyond climate adaptation (Jones et al., 2012). These co-benefits include, among others, biodiversity conservation through enhanced habitat conditions; climate mitigation through increased carbon sequestration; conservation of traditional knowledge, livelihood and practices of local communities; improved recreation and tourism opportunities; enhanced food security (Demuzere et al., 2014; Naumann et al., 2011; Vignola et al., 2009; Munang et al., 2013b,c). Even though EbA approaches generally lack quantitative estimates of the adaptation potential (Jones et al., 2012), there is increasing evidence that they can provide flexible, cost- effective and broadly applicable alternatives to cope with the magnitude, speed and uncertainty of climate change (Munang et al., 2013a). For these reasons, EbA has rapidly become an important aspect of the international climate policy framework. As an example, the European Union recent climate adaptation strategy (EC, 2013) explicitly encourages the adoption of green infrastructure and ecosystem-based approaches to adaptation.

Cities are particularly vulnerable to climate change, due to the large and growing urban population worldwide and the complex patterns of economic assets, infrastructures and services that characterize them. Hence, achieving climate adaptation in urban areas is pivotal for sustainable development, as shown by growing actions undertaken by cities to pursue adaptation (Rosenzweig et al., 2010), as well as guidance documents produced to assist in this endeavor (e.g, ICLEI, 2010). Picketts et al. (2013) suggested that climate adaptation "is well suited to local levels of governments, as citizens can participate in creating targeted adaptation strategies that address the important regional impacts, and these strategies will provide tangible benefits to local residents". Along the same lines, Measham et al. (2011) consider planning at municipal level as a key avenue to mainstream adaptation actions.

EbA can play an important role in urban contexts and help to cope with increased temperature, flood events and water scarcity, by reducing soil sealing, mitigating heat island effect and enhancing water storage capacity in urban watersheds (Muller et al., 2013; Grimsditch, 2011; Gill et al., 2007). EbA in cities include approaches based on the design and improvement of green and blue infrastructures (e.g., urban parks, green roofs and facades, tree planting, rivers, ponds), as well as other types of interventions that use ecosystem functions to provide some form of adaptation to climate risks (e.g., measures to reduce soil imperviousness) (Roberts et al., 2012; Doswald and Osti, 2011). In cities, most ecosystems are "urban ecosystems", i.e., ecosystems where the built infrastructure covers a large proportion of the land surface, or those in which people live at high densities (Pickett et al., 2001; Savard et al., 2000). Urban ecosystems include all green and blue spaces in urban areas, and typically have a low level of naturalness, being heavily managed or entirely artificial (Gómez-Baggethun and Barton, 2013). Green roofs are an example of urban ecosystems almost exclusively determined by humans and that require regular maintenance (Oberndorfer et al., 2007). The term EbA measures is commonly used also in cities to refer to the use of urban ecosystems to provide services that help to adapt to climate change (e.g., Zandersen et al., 2014; Doswald et al., 2014; Munroe et al., 2012; Doswald and Osti, 2011).

The recent literature has addressed the potential role of EbA in cities (Müller et al., 2013; Bowler et al., 2010; Berndtsson, 2010). In particular, Demuzere et al. (2014) presented a comprehensive analysis of the available empirical evidence about the contribution of green infrastructures to climate change adaptation in urban areas. Nevertheless, the concept of EbA is still relatively new for cities, and little evidence is available on the inclusion of EbA measures in actual urban plans and policies (Wamsler et al., 2014). Urban planning, at least in more industrialized countries, has been increasingly addressing climate adaptation strategies and actions, as shown by recent reviews of planning documents undertaken for cities in Europe (Reckien et al., 2014), the UK (Heidrich, 2013), Australia (Baker et al., 2012) and North America (Zimmerman and Faris, 2011). However, none of these papers address specifically EbA.

The grey literature contains several collections of experiences, but they focus either on urban adaptation in general, with little emphasis on ecosystem-based approaches (EEA, 2012), or on EbA, with little emphasis on urban areas (Doswald and Osti, 2011; Naumann et al., 2011; Andrade Pérez et al., 2010). The majority of the EbA case studies presented in the latter reports is related to natural areas, coastal zones, agriculture and forestry. An exception is represented by the work of Kazmierczak and Carter (2010), which compiles a database of case studies to showcase EbA approaches in cities. However, these case studies do not specifically relate to planning, but to a broader set of initiatives, including for example incentive schemes, physical infrastructure delivery, guidance documents, etc. In conclusion, the extent to which EbA approaches are actually included in planning at the urban level is largely not documented.

This paper addresses this gap by developing a classification of EbA and a scoring system to analyze the treatment of EbA in urban climate adaptation planning, and apply it to a sample of plans in Europe. Specifically, the paper aims at answering questions related to:

- The types of EbA measures that are included in climate adaptation plans (What are the most common ones? To what climate change impact do they aim to respond?)
- The extent to which EbA measures are considered and described in climate adaptation plans (In what parts of the planning documents are EbA measures present? How well and how consistently are they treated?)

The ultimate purpose of the paper is to provide an overview of the current state of the art related to the inclusion of EbA in urban planning, and use it to identify and discuss the main shortcoming and propose possible solutions. First, we describe the review framework, which includes the identification of EbA measures that are relevant for urban adaptation. We then present the sample of planning documents, and the method that was used to extract information relevant to the study. Afterwards, we present the results of the evaluation. Finally, we discuss the main findings and conclude by providing recommendations to improve future practice in urban planning.

2. Methods

2.1. Classification of EbA measures

As a first step in our study, we identified and classified possible measures for EbA that are relevant for urban areas. Many examples and descriptions of EbA measures are present in the literature (Doswald et al., 2014; Zandersen et al., 2014; Jones et al., 2012; Doswald and Osti, 2011; TNC, 2009). However, to the best of our knowledge, a comprehensive classification of typologies of EbA measures that can be employed in urban areas has not been developed. Most studies focus on EbA in agriculture and forest areas (e.g., Vignola et al., 2009) or anyway do not provide a classification of different EbA typologies. The closest attempt to produce a list of possible EbA in urban contexts was found in EEA (2012). Here, different types of measures are associated to the climate change impacts they aim at reducing, i.e., heat, flooding and water scarcity. These three impacts reflect the expected effects of the current projections of average climate change: the increase in duration, frequency and/or intensity of heat waves, extreme precipitation events and droughts (Barriopedro et al., 2011; Giorgi et al., 2011; Hoerling et al., 2012).

The list proposed by EEA (2012) was revised and integrated with other typologies found in the literature. This resulted in the classification presented in Table 1, where definition, rationale and supporting references are provided for each measure. Measures are associated to the climate change impact they are meant to reduce, even though it is recognized that synergies occur. For example, green roofs may contribute to reduce runoff water quantity (Czemiel Berndtsson, 2010), in addition to building cooling. The EbA measures play at different spatial scales, ranging from building-scale interventions (e.g., green roofs and walls) to urban-scale interventions (e.g., city-wide green corridors). Despite their difference in scale, the identified measures are all within the scope of urban plans, hence they can be (at least partly) implemented by actions proposed in planning instruments. Measures such as river renaturalization, in most cases, cannot be handled within the border of a city alone. However, urban plans have the possibility to implement these interventions (at least for the urban sector of rivers), as well as to promote coordination with other planning levels (e.g., regional planning, river basin planning). For this reason, these measures have been included in the proposed classification of EbA measures relevant for urban areas.

2.2. Selection of the sample of plans

There are many planning instruments that address climate change adaptation at the local level. We use the term 'climate adaptation plan' to refer in general to plans that include strategies to reduce vulnerability to climate change in cities, even though the actual name of the plan might be different. At European level, there is little information on the range of plans being developed under the rubric of climate action planning, and to our knowledge there is no central database or agency collecting this information. For this reason, we decided to focus on a sample of cities considered active in climate change adaptation, by referring to the "C-40" initiative (http://www.c40.org). The C-40 was established in 2005 as a network of large cities worldwide that are taking action to reduce greenhouse gas emissions and to face climate risks. This sample offers the advantage of providing information on different initiatives undertaken by cities that have been particularly active in climate adaptation strategies. This is consistent with the purpose of this study, which is to offer an overview of the extent to which EbA measures are included in planning instruments of cities engaged in climate actions, as opposed to evaluating the performance of different cities or geographical regions. Among the cities of the C-40 database, we selected the ones belonging to Member States of the European Union. This resulted in a sample of 14 cities, namely Amsterdam, Athens, Barcelona, Berlin, Copenhagen, Heidelberg, London, Madrid, Milan, Paris, Roma, Rotterdam, Stockholm, Venice and Warsaw. A cross-check with European-level data sets on heat, floods and water scarcity published by the European Environmental Agency[1] revealed an even presence of climate change challenges in the city sample: seven of the selected cities are located in regions affected by heat waves, seven by floods and six by water scarcity.

We then gathered all the urban climate change responses in the form of planning documents approved by the relevant municipal authority, and available on the internet. This resulted in the list of planning documents listed in Table 2. As can be seen, all the selected cities have approved a Sustainable Energy Action Plan (SEAP). The SEAP is the key planning instrument provided for by the "Covenant of Mayor", a local-level initiative supported by the European Commission that promotes the involvement of local authorities in responding to climate change. Even though originally SEAP were to address mostly measures for CO_2 emission reduction, energy efficiency and renewable energy, they have expanded their scope to include more broadly all climate-related measures (Zanon and Verones, 2013). As shown in Table 2, some cities approved additional plans related to climate change, which were also included in our analysis.

2.3. Analysis of the content of the plans

Prior to the analysis, the content of the plans was divided into four components: information base; vision and objectives; actions; implementation. These components represent thematically different parts of the plans. The *information base* includes the analysis of current conditions and future trends (typically presented in the introductory parts of the planning documents), which is performed in order to provide a basis for the subsequent development of the plan's objectives and actions. *Vision and objectives* include the statement of the ambition and of the general and specific objectives that a plan intends to achieve. *Actions* include all the decisions, strategies and policies that the plan propose, in order to achieve its objectives. Finally, *implementation* refer to all measures (including budget-related ones) proposed to ensure that actions are carried out. This classification of plan components is a modified version of the one proposed by Baker et al. (2012), which comprises also a fifth component: options and priorities, i.e., the development and prioritization of alternative solutions. This component was not included here because largely missing from the planning documents considered in this study. The proposed four-component approach is consistent (even though it uses a different terminology) with the one used by Heidrich et al. (2013) to review adaptation and mitigation plans in the UK.

A direct content analysis (Hsieh and Shannon, 2005) was performed, by reading all the documents associated to the selected plans, and identifying – for each of the four components – the content related to EbA measures, using the classification presented in Table 1. This approach was preferred to a keyword-based analysis, given that there is not yet a well-established terminology in this field, and plans use a wide range of different wording to refer to concepts related to EbA, and to ecosystem services in general (Braat and de Groot, 2012). Hence, we searched for the presence of the different measures, irrespective of whether the plan used the term "EbA" or not to describe them. By breaking down the analysis in the four plan components, it was possible to test also the overall consistency of the plan with respect to EbA-related issues, i.e. the extent to which the EbA-related analysis contained in the information base provide an appropriate factual basis for developing objectives, which in turn are linked to suitable actions, and implementation proposals (Bassett and Shandas, 2010).

The content analysis followed a two-step process. First, the presence of the different EbA measures in each plan component was searched, by using the following guiding questions:

- *Information base*: Does it contain data/statements/analyses that show awareness about EbA?
- *Vision and objectives*: Are there objectives associated to the development/enhancement of EbA measures?
- *Actions*: Are there actions aimed at developing/enhancing EbA measures?
- *Implementation*: Do the implementation provisions include reference to EbA measures?

Second, whenever the answer to the previous questions was positive, the content was further analyzed in order to assess the

[1] The maps are available at http://eea.maps.arcgis.com (heat and floods) and http://www.eea.europa.eu/data-and-maps/figures/drought (water scarcity and drought).

Table 1
The classification of EbA measures for urban areas adopted in this research (building on the list proposed by EEA, 2012).

EbA measure	Climate change impact	Rationale	References
a. Ensuring ventilation from cooler areas outside the city through waterway and green areas	Heat	If carefully designed, urban waterways and open green areas have the potential to create air circulation and provide downwind cooling effect	Oke (1988)
b. Promoting green walls and roofs	Heat	Vegetated roofs and facades improve the thermal comfort of buildings, particularly in hot and dry climate	Skelhorn et al. (2014); Bowler et al. (2010); Castleton et al., 2010).
c. Maintaining/enhancing urban green (e.g., ecological corridors, trees, gardens)	Heat	Green urban areas reduce air and surface temperature by providing shading and enhancing evapotranspiration. This cooling impact is reflected, to some extent, also in the building environment surrounding green areas.	Yu and Hien (2006); Demuzere et al. (2014)
d. Avoiding/reducing impervious surfaces	Flooding	Interventions to reduce impervious surfaces in urban environments (e.g., porous paving; green parking lots; brownfield restoration) contribute to slow down water runoff and enhance water infiltration, reducing peak discharge and offering protection against extreme precipitation events.	Farrugia et al. (2013); Jacobson (2011)
e. Re-naturalizing river systems	Flooding	Restoring river and flood-plain systems to a more natural state in order to create space for floodwater can support higher base flows, reducing flood risk. Restoration interventions include, for example, the establishment of backwaters and channel features and the creation of more natural bank profiles and meanders.	Burns et al. (2012); Palmer et al. (2009)
f. Maintaining and managing green areas for flood retention and water storage	Flooding, water scarcity	Vegetated areas reduce peak discharge, increase infiltration and induce the replenishment of groundwater. To enhance this, retention basins, swales, and wet detention systems can be designed into open spaces and urban parks.	Foster et al. (2011); Cameron et al.(2012)
g. Promoting the use of vegetation adapted to local climate and drought conditions and ensuring sustainable watering of green space	Water scarcity	Green space may exacerbate water scarcity in urban areas. To limit this problem, interventions can be directed at choosing the most appropriate tree species (that are drought resistant but still suitable as a part of the urban green space), and designing sustainable watering systems (e.g., using grey water or harvested rainwater)	EEA (2012)

extent to which EbA measures were addressed, by using the four-level scoring system presented in Table 3. The assigned scores were cross-checked by all authors of this research. Finally, an average score was obtained for each type of EbA measure by computing the average value obtained by that measure in all the plans where the measure is found, and for all plan components.

In this study we reviewed the English translation of the planning documents, which was always available except for the plans of Milan, Venice and Rome, for which we reviewed the original documents in Italian. Fearing that translations might be reduced versions of the original plans (and omit important details), we checked also the original documents, whenever we had the required language skills, i.e. for the plans written in Spanish and French. These checks showed that the translations were accurate and complete. Based on this, we concluded that the English translations are adequate for the purposes of this study.

3. Results

3.1. What EbA measures are included in the plans and how well are they addressed?

Consistently with the purpose of the study, the results are not presented and discussed in terms of the quality of the individual plans, but they are broken down by EbA measure and by plan components. A total of 44 EbA measures were found in the selected plans. Fig. 1 illustrates the breakdown in the seven types described in Table 1. As can be seen, measures *c* (maintaining/enhancing urban green) and *f* (maintaining and managing green areas for flood retention and water storage) are the most common ones, and are found in 85% of the selected plans. Examples of measures *c* include efforts to increase green areas and neighborhood gardens (Paris), proposals for enhancing the connectivity among existing green areas through the design of green corridors and rings (Milan) and the use of plants to provide shade in new industrial estates (Amsterdam). Measures *f* consist, for example, in the creation of new wetland areas and ponds (Berlin), and the design of green spaces to store rainwater in the event of torrential rain (Copenhagen).

Measure b (Promoting green walls and roofs) is found in 57% of the plans. For example, Paris's plan contains provisions for the establishment of roof and wall gardens (measure *b*), including the identification of priority spots for this type of green infrastructures. Measure *e* (re-naturalizing river systems) is found in 29% of the plans. In Madrid, for example, this consisted in a series of bank improvements projects aimed are reducing flood hazard and expanding riverside public space. Measures *a*, *d* and *g* (respectively, ensuring ventilation, avoiding/reducing impervious surfaces, and promoting climate-adapted vegetation and sustainable watering) are less common, and found only in 14–21% of the plans. For example, concerning measure *a*, cold air networks to ensure ventilation and prevent over-heating are mentioned in Copenhagen's plan, whereas Madrid's provides for the promotion of *ecobarrios* where ventilation will be one of the factors considered in the design of greening interventions. Berlin's plan attains the reduction of impervious surfaces (measure *d*) through renovation projects for buildings and school playgrounds that include interventions to improve soil permeability and in situ infiltration. Finally, concerning measure *g*, Venice's plan promotes the use of autochthonous species adapted to the local climate, and Madrid's contains detailed guidelines for "sustainable gardens" with recommenda-

Table 2
List of the planning documents reviewed in this research.

City	Name of the plan	Year	Source
Amsterdam	Amsterdam: a different energy (SEAP)	2010	http://mycovenant.eumayors.eu/
	Amsterdam definitely sustainable	2011	http://www.nieuwamsterdamsklimaat.nl/
	New Amsterdam climate	2010	http://mycovenant.eumayors.eu/
	Outspokenly sustainable-perspective 2014	2009	http://www.nieuwamsterdamsklimaat.nl/
	Structure vision for Amsterdam 2014	2008	http://www.nieuwamsterdamsklimaat.nl/
Barcelona	The energy, climate change and air quality plan for Barcelona (SEAP)	2011	http://mycovenant.eumayors.eu/
Berlin	Berlin environmental relief programme (10 years) (SEAP)	2011	http://mycovenant.eumayors.eu/http://http://www.berlin.de/
Copenhagen	Copenhagen climate adaptation plan (SEAP)	2011	http://mycovenant.eumayors.eu/ http://www.kk.dk/
Heidelberg	Climate protection commitment Heildelberg (SEAP)	2010	http://mycovenant.eumayors.eu/
London	Delivering London's energy future (SEAP)	2010	http://mycovenant.eumayors.eu/
	The London Plan: spatial development strategy for a greater London	2008	http://www.london.gov.uk
Madrid	Plan de uso sostenible de la energia y prevencion de cambio climatico (SEAP)	2008	http://mycovenant.eumayors.eu/
Milano	Piano per l'energia sostenibile ed il clima (SEAP)	2009	http://mycovenant.eumayors.eu/
Paris	Paris climate protection plan (SEAP)	2004	http://mycovenant.eumayors.eu/
Roma	Piano d'azione per l'energia sostenibile per la città di Roma (SEAP)	2010	http://mycovenant.eumayors.eu/
Rotterdam	Investing in sustainable growth, Rotterdam programme on (SEAP)	2010	http://mycovenant.eumayors.eu/
	Rotterdam climate city, mitigation action programme	2010	http://www.rotterdamclimateinitiative.nl/
	The new Rotterdam, Rotterdam climate initiative	2009	http://www.rotterdamclimateinitiative.nl/
Stockholm	Stockholm action plan for climate and energy (SEAP)	2012	http://mycovenant.eumayors.eu/ http://www.stockholm.se/
	Stockholm climate initiative	2010	http://www.stockholm.se/
Venezia	Piano d'azione per l'energia sostenibile (SEAP)	2013	http://mycovenant.eumayors.eu/
Warsaw	Sustainable action plan for energy Warsaw (SEAP)	2011	http://mycovenant.eumayors.eu/

tions for the selection of plant species and sustainable watering systems.

The results of the application of the scoring systems (presented in Table 3) were used to compute an average score for each type of EbA measure (Fig. 2), representing the average value obtained by the measure in all the plans where the it is found, and for all plan components. As can be seen, the average score ranges from 1.1 (achieved by measures *a* and *g*) to 2.4 (measures *e*). Measures *c* and *f*, which are the most frequently found, are also the ones with the highest scores, together with action *e*.

3.2. How are EbA measures reflected within plan components?

Fig. 3 shows in which plan components (see Section 2.3) EbA measures are reflected. 91% of the measures are present in the *vision and objectives* component. This means that, when a plan includes an EbA measure, this is very often listed as (part of) one of the objectives that the plan intends to achieve. For example, Paris's plan objectives include the development of a multi-year scheme to promote roof gardens. 91% of the EbA measures are addressed in the *actions* component, meaning that the plans include specific poli-

Table 3
Scoring system used to evaluate the plan components.

Score	Information base	Vision and objectives	Actions	Implementation
0	No evidence of information related to EbA measures	No evidence of objectives related to EbA measures	No evidence of EbA measures	No evidence of implementation provisions related to EbA measures
1	Acknowledges EbA measures only generally (not in connection to specific climate change issues)	Mentions EbA-related objectives, but lacks further definition	Mentions EbA measures, but lacks further definition	Mentions implementation provisions related to EbA measures, but lacks further definition
2	Acknowledges EbA measures in the context of specific climate change issues	Includes EbA measures in the objectives and provides some details on their specific content and how to pursue them	Includes EbA measures in the actions and provides some details on their application and activities	Includes EbA-related implementation provisions and provides some details on their application
3	Acknowledges EbA measures and describes (at least qualitatively) the potential climate changeadaptation effects	Includes EbA measures in the objectives, provides details on their content, and describes links with related planning and policy processes at the local/regional level	Includes EbA measures in the actions, provides information on their application and activities, including locally-specific details	Includes EbA-related implementation provisions and provides information on their application, including details on budget, responsible bodies, etc

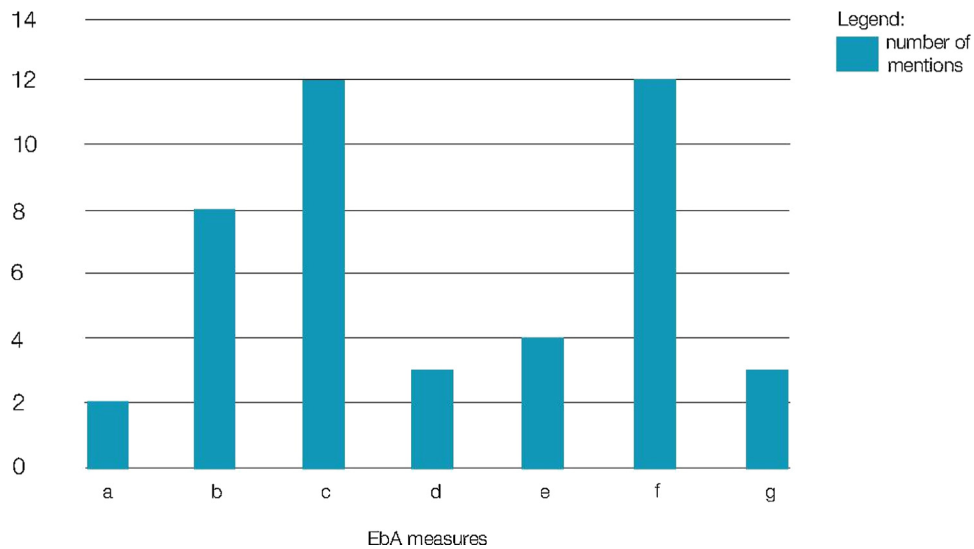

Fig. 1. Number of mentions of the seven types of EbA measures (see legend in Table 1) in the sample of plans.

cies or activities to attain them. For example, Milan's plan includes a series of linear greening interventions along canal banks, roads, biking routes, etc. The *information base* component of the plans contains data relevant to EbA measures only in 79% of the cases. That is, 21% of the measures found in the plans are not supported by any baseline information or analysis. Even when baseline information is present, this consists mostly of general statements and descriptions. For example, Berlin's plan contains descriptions of how energy efficiency of buildings or industry could be usefully combined with projects to support sustainable local water management systems, by increasing the permeability of soil and planting vegetation.

The *implementation* component of the plans performs even more poorly: references to EbA measures are found in only 52% of the cases. Therefore, about half of EbA measures are not associated to any action to ensure that they are carried out. When information about implementation measures are present, this consists mainly of budget-related details, as for example in the case of Madrid's plan (where each action is linked to a plan of implementation and budget), and Rotterdam's, where there are indications about green roofs subsidies.

In order to assess how well EbA measures are reflected within the different plan components, we computed the average score obtained by all EbA measures that are found in each of the four components. For example, out of the 44 EbA measures, 35 are present in the *information base* component of the selected plans. The average score represents the average of the scores obtained by these 35 EbA according to the scoring system presented in Table 3 (secondo column: information base). The results (Fig. 3) show that *actions* component scored the highest (average score: 2.8), followed by the *implementation* (2.5), the *vision and objectives* (2.2) and the *information base* (1.8). Concerning the good performance of *actions*, examples include London's plan, which describes in detail the actions and associated sub-actions, specifies the responsible bodies and identify links with other plans and policies. Similarly, Madrid's plan provides action fact-sheets, with the identification

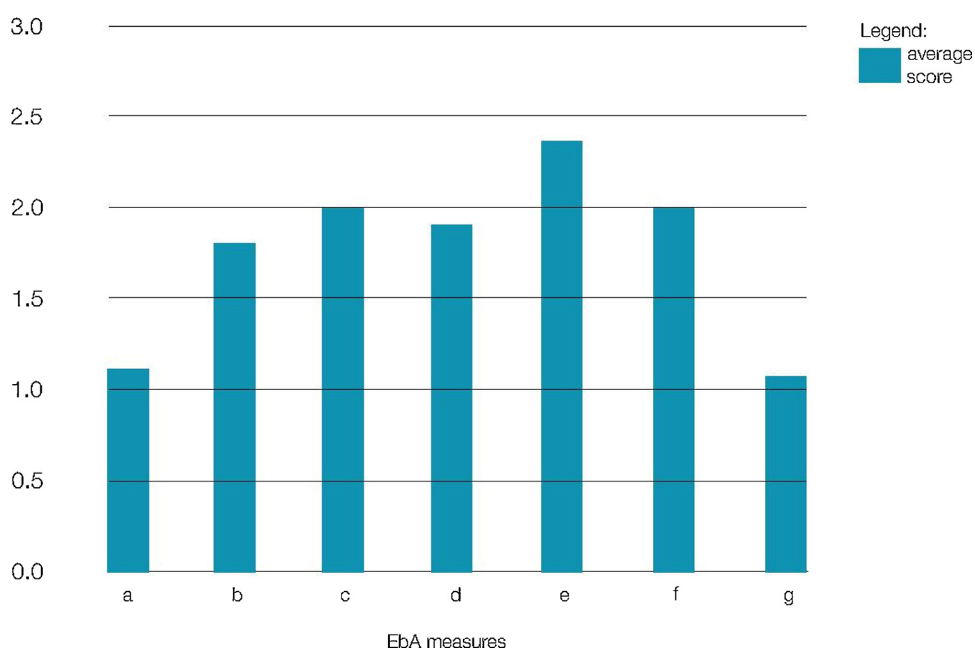

Fig. 2. Average scores of the seven types of EbA measures.

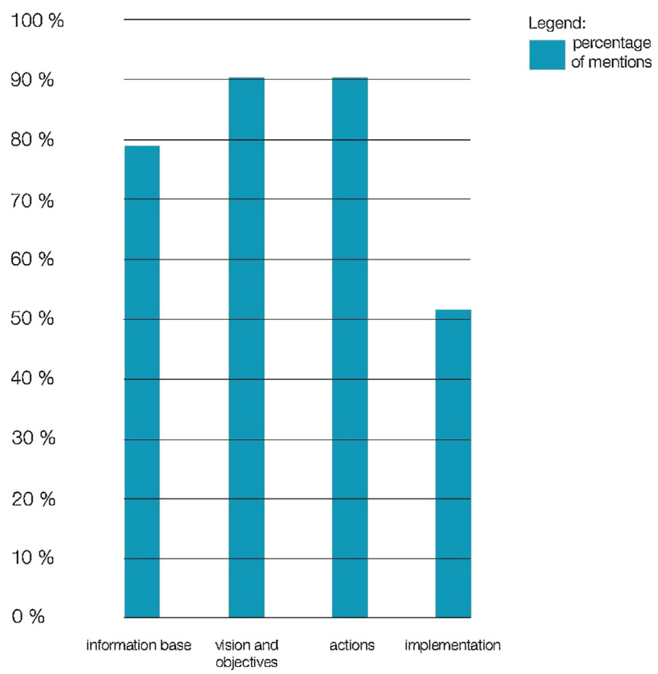

Fig. 3. Frequency of presence of information about the 44 EbA measures in the different plan components.

of responsible bodies and associated budget. The poorer scores of the *visions and objectives* component are due to the fact that their description tend to be very general. The *information base* typically lacks details on the links between measures and climate-related issues, particularly concerning the results expected from the application of the measure.

Finally, Fig. 4 provides a visual overview of the distribution of information on the identified EbA measures across plan components. This figure helps to understand how consistency EbA measures are treated across the different plan components, and where the gaps are. The figure shows that the 44 EbA measures identified in the plans can be grouped in six categories:

- Measures addressed in all the four plan components, from the *information base* through the *implementation*. This is obviously the most desirable situation, but occurred only for 45.5% of the EbA measures. In all other cases, at least one component is lacking;
- Measures addressed in the first three components of the plans, but not in the *implementation* part. This occurs for 22.7% of the EbA measures;
- Measures addressed only in the *vision and objectives* and *actions* with no links to the *information base* or *implementation* (13.6%);
- Measures addressed only in the *information base* and *vision and objectives*, with no follow-up in the rest of the plan (6.8%);
- Measures addressed in the *information base* only, with no follow-up in the rest of the plan (2.3%)
- Measures addressed in the *vision and objectives*, *actions* and *implementation* components, with no links to the *information base* (2.3%).

4. Discussion

Ecosystem-based climate adaptation strategies have been increasingly promoted in the literature, as well as in policies and practices, acknowledging their environmental, social and economic co-benefits (Jones et al., 2012; Doswald and Osti, 2011; TNC, 2009). In parallel, the recent scientific literature has shown a growing interest in analyzing the content of climate adaptation plans at the local level, in order to assess their quality and effectiveness and to formulate suggestions for future improvement (Kumar and Geneletti, 2015; Reckien et al., 2014; Heidrich et al., 2013; Baker et al., 2012; Tang et al., 2010). This in recognition of the important role played by local administrations in addressing climate change challenges, being often ahead of national legislation and actions (Rosenzweig et al., 2010). However, to the best of our knowledge, there are no published studies that address the combination of these two issues, i.e., the actual inclusion of EbA measures in urban climate adaptation plans. More in general, little evidence is available on the up-take of EbA measures in urban areas, given that most of the published work focuses on natural areas, agriculture and forestry (Doswald and Osti, 2011). This research contributed to fill this gap, by shedding some light on what EbA measures are most commonly found in plans, how well they are addressed, and how consistently throughout the different plan components.

Measures *c* and *f* are the most common ones, showing that there is strong awareness of the role that green areas play in addressing climate change challenges, both in terms of mitigating heat waves (measure *c*) and preventing floods (measure *f*). The frequency of these measures is perhaps not surprising giving that they result in the enhancement of green areas, which is a typical objective that planners pursue to improve the urban space for a variety of purposes that go beyond climate change adaptation (e.g., providing recreation opportunities, improving air quality) (Tzoulas et al., 2007). So, their frequency could be explained by the fact that these measures rely on actions that are part of the standard portfolio that planners have been employing for decades. However, a critical issue that we detected is that the proposal of these EbA measures in the plans is rarely backed-up by specific information on the expected contribution in terms of climate change adaptation, as well as the target beneficiaries. That is, in the revised plans, the enhancement of green areas to reduce heat or to prevent floods is typically proposed as a general measure that will do some good, without providing details and justification for critical decisions, such as the design and the location of these interventions, and the distribution and vulnerability of the expected beneficiaries. These issues play a key role in determining the effectiveness of the measures (Kleerekoper et al., 2012; Kazmierczak, 2012).

Green walls and green roofs (measure *b*) are found in more than half of the cities. These measures are well covered by the literature, which offers ample debate on the effectiveness of vegetated roofs and facades to improve the thermal comfort of buildings, providing data for different climate zones and recommendations for implementation (Santamouris, 2014; Cook-Patton and Bauerle, 2012). The relatively low presence of measure *d* is somehow surprising, especially considering that EbA measures to reduce impervious surfaces include interventions at the local level, which are often relatively cheap and do not pose particular challenges in terms of coordination with other policies or plans (Carmon and Shamir, 2010). Therefore, they are quite straightforward to include in climate adaptation plans, and the fact that they are mentioned only in less than one third of the plans suggest that there is still need to increase awareness in local administration officers and planners. This finding is consistent with previous research (Brabec, 2009), showing that the careful design of impervious areas is largely overlooked.

Measure *a* is the least frequently encountered measure. One reason may be that the effectiveness of this measure is related to the urban morphology more in general. Elements such as building footprint, density and height and street layout have a strong influence on urban ventilation corridors (Wong et al., 2010). Hence, the design of urban waterways and open green areas that create air circulation needs to be undertaken jointly with other actions related to the built environment that go beyond the content of climate adaptation plans. This hampers the possibility for climate adapta-

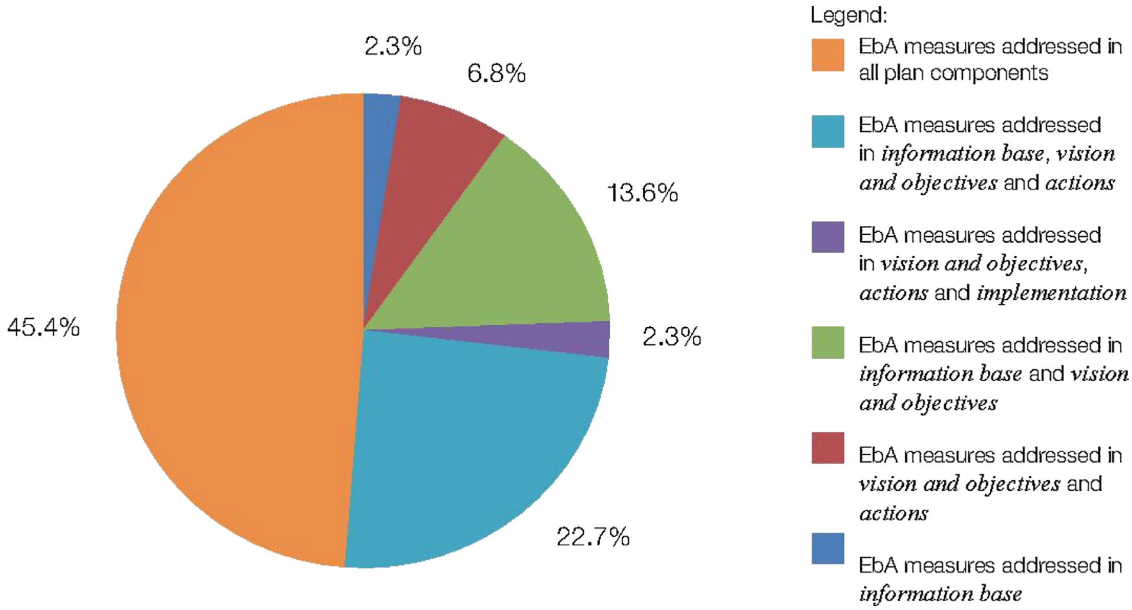

Fig. 4. Distribution of information on the identified EbA measures across the plan components (see text for further explanation).

tion plans to advance this type of EbA measures, requiring strong coordination with other planning instruments, such as urban plans. Measure *g* was also rarely found in plans, but this may be explained by the fact that it encompasses a more limited set of actions, which may be relevant only in specific climate conditions.

Finally, the analysis revealed that all the cities affected by water scarcity included in their plans at least one EbA measure to cope with this climate change challenge. The same occurred with cities affected by floods. Concerning heat waves, all but one city proposed EbA measures to cope with it. This suggests that there is a general awareness about the portfolio of possible EbA measures, and the capability to select those that better fit the needs of a particular contexts. The main critical point resides in the depth of the analyses performed to support and design a specific measure, as described next.

By tracking the treatment of EbA measures in the four plan components, it was possible to test also the overall consistency of the plan, i.e. the extent to which the EbA-related analysis contained in the information base provides an appropriate factual basis for developing objectives, which in turn are linked to suitable actions, and finally to implementation proposals. Our analysis reveals that the most frequent missing link involves the implementation component. This component is often absent, with many cases of EbA measures that are addressed throughout the plan, but in the implementation part. Even when present, this component has the poorest performance, as the content tends to be vague with few tangible elements that may be used to track how planners envisage to implement the measures. This problem was also found by other studies of climate adaptation plans, such as Tang et al. (2010)' which concluded that implementation provisions were associated to relatively few strategies.

One final note concerning possible future developments of this research. This study proposed a classification for EbA measures and a scoring system to assess the extent to which they are included in plans. Further work can be done to refine and improve this classification, which could be ultimately employed as a basis for the development of EbA reference manuals and handbooks for planners. The relatively small size of the sample of cities, and the way it was selected (i.e., by looking at cities that are already active in climate adaption), do not permit to reach conclusions on the "state of preparedness" (Heidrich et al., 2013) of different cities or regions in Europe, with respect to the adoption of EbA measures in their climate adaptation plans. As acknowledged in Section 2, the choice of the sample is biased in that it includes cities that represent positive examples of climate adaptation, and that often have a consolidated past in sustainable planning. This is consistent with the objective of the study, which was to assess the inclusion of EbA measures in cities engaged in climate actions, in order to understand what are the most common measures and how they are developed in their planning instruments. A follow-up study could employ the same approach to investigate a larger sample of cities, selected in a way to be representative of the conditions in different geographical areas. For example, future studies could focus on individual countries, and select cities representative of socio-economic and demographic conditions across those countries. Another possible follow-up of this work could shift the focus from climate adaptation plans to other types of plans at the urban scale, such as particularly spatial plans. This will allow to evaluate and compare the level of uptake of EbA measures in different contexts and different planning instruments, and to provide context-specific directions and recommendations for future improvements.

5. Conclusions and recommendations

As Munang et al. (2013a) put it, "integrating and mainstreaming EbA into decision making frameworks and planning processes are imperative". The results of this study suggest that EbA measures are finding their way in climate adaptation plans, in response to a broad range of climate change challenges. However, most plans are affected by a lack of specificity and details that may hamper the possibility for these measures to be actually implemented, as well as their overall effectiveness in reducing population vulnerability. Based on our findings, we can formulate the following recommendations to improve the consideration of EbA measures in climate adaptation plans:

1. The baseline information upon which EbA measures are proposed and designed needs to be enhanced. Methods to assess the existing stock of green/blue infrastructures, and their potential to provide climate adaptation services must be mainstreamed in planning practice. Particularly, assessments of the flow of ecosystem services at local scales are often missing, given that

many climate change impact and vulnerability studies provide results at larger scales, limiting their usefulness for developing adaptation strategies at the local scale (Vignola et al., 2009). A better knowledge base, including information on spatial pattern of vulnerability, would allow to better target the design and implementation of EbA measures.

2. Co-benefits associated to EbA need to me made more explicit. One of the strongest motivation for promoting EbA approaches is that they bring environmental and socio-economic benefits, beyond climate adaptation. A more formal analysis of the magnitude of the co-benefits need to be promoted in planning, in order to provide a stronger rationale for decisions involving EbA. Ideally, comparisons between EbA and alternative adaptation measures should be performed, as advocated by Jones et al. (2012). These analyses can take advantage of the methodologies and findings presented in the growing literature on the assessment and evaluation of ecosystem services (Kareiva et al., 2011), including its emerging streams focused on spatial planning (McKenzie et al., 2014) and impact assessment (Geneletti 2013, 2011).
3. Interaction between climate adaptation plans and other planning instruments at the local level needs to be strengthen. Many EbA measures require space, hence compete with other land uses and needs in areas (urban settlements) where land resources are often scarce. A strong coordination with urban plans and other actions and policies is required to ensure that the proposed EbA measures are both feasible and desirable. The issue of integration between climate adaptation actions and other planning efforts has been raised by Preston et al. (2011), but has not received the required level of attention, even by the scientific literature.

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