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Assessment framework to assist ecosystem-based adaptation implementation at local level: evidence from Spain and Portugal

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Abstract

Technical Summary. Climate hazard events, such as floods and heatwaves, are becoming more frequent and severe. This paper focuses on coastal urban areas and addresses the need for implementing effective ecosystem-based adaptation (EbA) measures. It highlights the importance of integrating EbA into urban planning to enhance resilience. The study proposes a comprehensive assessment framework to guide EbA implementation process at the local level. Governance system, policy framework, and funding sources are identified as key factors influencing the process. Within governance structures, the study focuses on cooperation, decision-making processes, scientific knowledge, and political support. Plans and strategies, regulations, international treaties, or agreements are recognized within policy sphere. The framework also considers the importance of sustainable funding mechanisms, including public–private partnerships and fiscal incentives, to ensure the long-term viability of EbA interventions. The framework's applicability and effectiveness are tested by assessing 10 implementation experiences in Spain and Portugal. The assessment underscores the need for adaptive governance and the inclusion of diverse stakeholders in planning and execution. The research concludes with the need for a systemic approach to integrating EbA into local adaptation strategies, to bridge the knowledge gap between researchers and practitioners, foster adaptation in coastal urban environments, and increase climate resilience.

1. Introduction

IPCC's projections for the present century foresee an acceleration of sea-level rise, along with an increase in the frequency of storms, heatwaves, flooding episodes, and related climate risks (Abadie et al., 2020). Between 1995 and 2015, 56% of damages caused by weather-related disasters accounted for flooding episodes (United Nations Office for Disaster Risk Reduction, 2019). The intensity and frequency of these episodes is causing important economic losses in Europe (Kumar et al., 2020). Estimates indicate that by 2035, 42% of Europe's population will be living in coastal areas, where climate risks are on the rise (Maul & Duedall, 2019). In this context, including measures capable to address climate change hazards in urban planning is gaining importance (Pour et al., 2020). Urban greening has been long recognised as an optimal strategy to improve living conditions (e.g., enhancing well-being and quality of life for urban residents, decreasing pollution, or providing recreational and aesthetic values, among others). It can contribute for water and climate regulation, while also providing additional ecosystem services highly relevant for human-well-being (e.g., air quality, biodiversity increase, food provision) (Esmail et al., 2022). Ecosystem-based adaptation (EbA) measures are presented as cost-effective interventions and solutions supported by nature, to restore natural or modified ecosystems, and address economic, social, and environmental problems related to climate change (Cohen-Shacham et al., 2019; Commission et al., 2015; Kumar et al., 2020).

In recent years, numerous articles have been published addressing the implementation of EbA and proposing frameworks for its evaluation and planning. Albert et al. (2021), Kumar et al. (2020), Raymond et al. (2017) and Sowińska-Świerkosz and García (2021) present evaluation frameworks for EbA planning, operationalisation, and implementation stages. Calliari et al. (2019) and Zölch et al. (2017) seek to evaluate EbA effectiveness under future climate conditions, while Liquete et al. (2016) and Raymond et al. (2017) are interested in assessing their co-benefits in urban and peri-urban contexts. Other frameworks

proposed are related to the conceptualisation of EbA (Brink et al., 2016; Matthews et al., 2015) and the integration of these measures in local adaptation plans and strategies (e.g., Dumitru et al., 2020; Geneletti & Zardo, 2016; Raymond, et al., 2017; Zölch et al., 2018). However, there is a recognised need to understand how assessment frameworks can facilitate the scaling up of EbA interventions at the local level. This involves a better knowledge of their benefits and performance, their recognition in local adaptation plans and governance models, and the availability of sustainable funding resources for their implementation and maintenance. This need is aligned with the European Union (EU) commitment to protect natural capital and value ecosystem services (Raymond, Frantzeskaki, et al., 2017) as recalled in different strategies (e.g., Biodiversity Strategy to 2030, Green Infrastructure strategies, EU Thematic Strategy on the Urban Environment, European Strategy on Adaptation to Climate Change, European Green Deal, Nature Restoration Law). Within this EU policy framework, green infrastructure has been recognised as a cost-effective alternative to more traditional adaptation approaches, such as grey or hard infrastructure (Davies et al., 2021). This perspective is reinforced by the European Research and Innovation Roadmap for Nature-Based solutions (NBS), which provides an advanced systemic understanding of, and approaches to, NBS development and implementation as a strategic action (El Harrak et al., 2023).

Despite the increasing recognition of EbA at the EU level,[1] its uptake remains significantly lower at local level, where landscape and urban planning are developed (Albert et al., 2021). Discussions on planning and governance of EbA are needed (Kabisch et al., 2022), as climate adaptation should occur at this scale, where adaptation strategies can be targeted and citizens can participate in their design and creation (Picketts et al., 2014). When including EbA in policy agendas, governance challenges emerge, such as policy incoherence or misalignment between different local, regional, or national administrations (Davies et al., 2021; Seddon et al., 2020). Adapting to governance challenges in EbA (Kabisch et al., 2017), and developing methodological approaches to integrate them into local planning (Tiwari et al., 2022) is crucial for an effective implementation and upscale of these measures. To integrate EbA in local governance, it is necessary to deepen our understanding of the underlying drivers and processes, such as the ecosystem regenerative potential of EbA and their governance embedding. (Frantzeskaki et al., 2016). One example is the interrelationship between nature and social systems, particularly the role that urban green initiatives can play in enhancing, among others, biodiversity, recreation opportunities, or climate change mitigation and adaptation. Advancing research in this field can provide systematic guidance to policy makers for the effective implementation of EbA (Wamsler et al., 2020).

While research has focused on analysing the co-benefits of EbA through individual case studies, the broader implications for policy, planning, and governance are often neglected (Frantzeskaki, 2019). To further advance the implementation of EbA strategies, a better understanding of the related instruments and policy processes operating at the local level is essential. This will increase its potential for replication and scaling up, narrowing the existing knowledge gap between researchers and practitioners. To this end, the main goal of this study is to develop a decision-support framework that identifies and evaluates key operational mechanisms involved in the local-level implementation of EbA initiatives. To this end, the main research goal of this study is to identify and evaluate key operational mechanisms involved in the local implementation of EbA initiatives and to develop a decision-support framework based on these insights. This research addresses the following specific questions: (i) What governance factors may influence the implementation process of EbA in local planning?; (ii) How effectively does the existing policy framework support the implementation and management of EbA?; and (iii) How adequate is the funding model for enabling effective implementation of EbA at the local level? Moreover, this study tests the assessment framework in a coastal urban context, specifically focusing on 10 case studies in Spain (Santander, Barcelona, and Barcelona Metropolitan Area, Vilanova i la Geltrú, Palma, Benidorm) and Portugal (Oeiras and Lisbon). Three of the assessed interventions are derived from the EU-funded SCORE project, while the remaining seven were retrieved from online EBA/NBS repositories. All of them propose solutions to address flooding hazards in coastal areas. By providing insights into the EbA implementation process, the proposed framework aims to enhance the efficacy and sustainability of adaptation efforts.

The remainder of this paper is structured as follows: first, the conceptual discussion of factors influencing the implementation process of EbA (Section 2). It follows the methodological foundations for the proposed framework and the selection of case studies to pilot it (Section 3). Section 4 includes the results of validating the framework in different case study areas, and the discussion of the criteria proposed, to finalise with the conclusions (Section 5).

2. Factors influencing the EbA implementation

Different actors intervene in the design and implementation process of EbA, which takes place in a variety of contexts. Planning appropriate solutions very often occur at local level, and the principles inspiring them (e.g., multifunctionality, equity, efficiency, and sustainability) should be reflected in policies developed at this scale (Leone, 2021).

The institutional proximity between local governments and citizens is a great opportunity for innovation, and the identification of societal demands, and challenges which inspire the design of policies. Laying out appropriate governance processes in cities contributes to embrace innovative environmental policies (Frantzeskaki et al., 2016). Governance refers to formal and informal institutions, rules, mechanisms, and processes, for planning and decision-making (Ostrom, 2005; Tacconi, 2011). The lack of proper governance structures hinders a wider implementation of EbA (Zölch et al., 2018). Very often legal frameworks and procedures, and other responsibilities related at this stage are distributed among multiple departments and agencies. This institutional fragmentation is a barrier for an effective implementation (McKenna & Naumann, 2017). In contrast, adaptive and flexible governance forms are enablers to reconceptualise green infrastructure for climate change adaptation (Kabisch et al., 2022; Matthews et al., 2015) and successfully implement and uptake these solutions (Cohen-Shacham et al., 2019; Kapos et al., 2019; Nesshöver et al., 2017; Wamsler et al., 2020).

[1]This article refers to Ecosystem-based Adaptation (EbA) as an approach that supports climate change adaptation through the sustainable management and restoration of ecosystems, with a strong emphasis on enhancing biodiversity and ecosystem services. In contrast, Nature-based Solutions (NbS) is a broader concept that encompasses EbA while also addressing wider societal challenges such as climate change mitigation, disaster risk reduction, and public health. While NbS includes a variety of nature-based actions, EbA specifically focuses on adaptation. Accordingly, in this article, any reference to climate change adaptation centered on biodiversity enhancement and human well-being is referred to as EbA

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When designing and implementing the EbA intervention, challenges such as overlapping competences, and shared management may arise, complicating the coordination with government agencies operating at different (vertical cooperation) or same levels (horizontal cooperation) (Droste et al., 2017; Matthews et al., 2015). Therefore, intragovernmental and intergovernmental cooperation is needed to harmonise policies and processes (Kapos et al., 2019; Leone, 2021). The decision process might be inspired by a power-relation, where the investment decision might be influenced by individual interests, such as land ownership (Seddon et al., 2020). While not having the necessary political support turns into a barrier (Mell et al., 2022), a co-creation process involving local citizens and stakeholder collaboration (Albert et al., 2021; Brink et al., 2016; Wamsler et al., 2020) facilitates public acceptance of the intervention (Anderson & Renaud, 2021; Sowińska-Świerkosz & García, 2021) and increases the legitimacy of the process (Nesshöver et al., 2017). Involving local actors in planning and implementation integrates their knowledge, customizing measures to the local context and thereby enabling the process (Niki et al., 2017).

The support of high community levels (governors, and other executive representatives) and greater involvement of stakeholders are key to integrate EbA and related concepts (e.g., regulation, provision, and cultural-based ecosystem services) in urban planning (Zölch et al., 2018). It also makes it possible to consider the valuation and accounting of multiple co-benefits in the decision-making process (Anderson & Renaud, 2021; Kabisch et al., 2022; Mell et al., 2022; Toxopeus & Polzin, 2021). The lack of know-how is identified as a frequent barrier in ecosystem management practices (Brink et al., 2016). To convey the necessary knowledge and evidence, scientists are to be involved in the process. More evidence on the effectiveness of the measures across spatial and temporal scales contribute to decrease the uncertainty surrounding their performance (Krauze & Wagner, 2019). Sufficient knowledge on EbA (Davies et al., 2021; Kapos et al., 2019; Mell et al., 2022; Schneider et al., 2021; Zölch et al., 2018) and existence of monitoring framework to guide the implementation process and follow-up their performance (Cohen-Shacham et al., 2019; Geneletti & Zardo, 2016; Nesshöver et al., 2017) are fundamental requirements for an adequate management of these interventions.

Moreover, it is important to understand, map, and balance the synergies and trade-offs associated with EbA implementation (Dumitru et al., 2020). While these interventions are often associated with significant benefits, it is equally important to consider whether they might have adverse societal impacts (e.g., green washing, land speculation leading to green gentrification) (Anguelovski & Corbera, 2023). Besides knowledge creation, dissemination through suitable channels is also recognised as a significant facilitator (Sarabi et al., 2019). Sharing experiences and lessons learnt through knowledge repositories (i.e., Oppla, Urban Nature Atlas) is a way to disseminate and increase the knowledge of existing experiences with potential to be replicated elsewhere.

In most situations, existing regulations have not been specifically designed to address EbA implementation (Davis McKenna & Naumann, 2017). Geneletti and Zardo (2016) identify the failure to explicitly refer to EbA in plans and regulations as a disabler for their implementation. Increasing the inclusion of EbA in adaptation plans and strategies, underpinned by ecosystem protection principles, may facilitate to encompass all environmental components and upscale these interventions. Avoiding conflicting regulations, i.e., between building permits and environmental plans which might hinder EbA implementation (Seddon et al., 2020). The existence of transnational treaties (Baravikova, 2020), as the EU strategies mentioned above, favours a wider inclusion of environmental regulations in national, regional, and local legislation, towards a green transition in cities.

Advancing EbA requires securing sufficient economic and financial resources sourced from diverse institutions, including but not limited to EU funds, national programs, local budget, private funds. Toxopeus and Polzin (2021) highlight the lack of coordination between private and public bodies as a key barrier for EbA financing. To overcome this challenge, innovative funding mechanisms might be explored, such as the establishment of partnerships to secure resources from different public and private institutions (Seddon et al., 2020). This could be the case of Public–Private Partnerships (PPP), which combine public sector regulations with the operational flexibility of the private sector (van Ham & Klimmek, 2017). Fiscal incentives, such as the reduction of municipal fees or ecological fiscal transfers can be suitable options to enable the successful implementation and uptake of EbA (Albert et al., 2021; Kumar et al., 2020). Moreover, the structural composition of the local budget plays a central role in shaping the integration of EbA into policy objectives. Ensuring a stable, and ideally growing, budget allocation may guarantee an effective embeddedness of these measures in local planning, overcoming the short-term allocation of financial resources to measures which co-benefits emerge in the long term (Niki et al., 2017).

3. Materials and methods

Building upon the review of barriers and enablers for EbA implementation identified in Section 2, it is proposed an assessment framework intended to support the decision process accompanying the EbA implementation process. There are three core categories which enfold the proposed criteria: (i) governance system; (ii) policy framework; (iii) funding model. To explore the governance system for EbA implementation at local level, the criteria considered include cooperation, management, decision process, and trade-offs and synergies. The criteria for assessing the adequacy of existing policy framework to implement and manage EbA include the existence of adaptation plans or strategies, fiscal incentives, and regulations, as well as global or bilateral treaties or agreements. Sustainable funding is necessary to drive the implementation of EbA. Identifying the source of funding, understanding the local budget structure, and the existence of fiscal incentives and partnerships as alternative financial support options are the criteria considered in this area Figure 1. Table 1 **¡Error! No se encuentra el origen de la referencia.** provides further details of the categories and criteria considered.

To test the assessment framework, there were selected several EbA experiences across the Iberian Peninsula. Case studies were limited to (i) EbA interventions suitable for flood mitigation; and (ii) located in coastal cities (as described in Eurostat (2024)). This study started by analysing various EbA implementation experiences, derived from the case study regions included in the EU SCORE project: a wetland restoration project in the beach of 'Platja Llarga' in Vilanova i la Geltrú (Province of Barcelona, Spain); a riparian reforestation in various intermittent rivers in Benidorm (Province of Alicante, Spain); and the green corridor of 'Eixo Verde e Azul' (Green-Blue Axis) in Oeiras (Metropolitan Area of Lisbon, Portugal). These initiatives were thoroughly analysed through the review of grey literature (adaptation plans, urban

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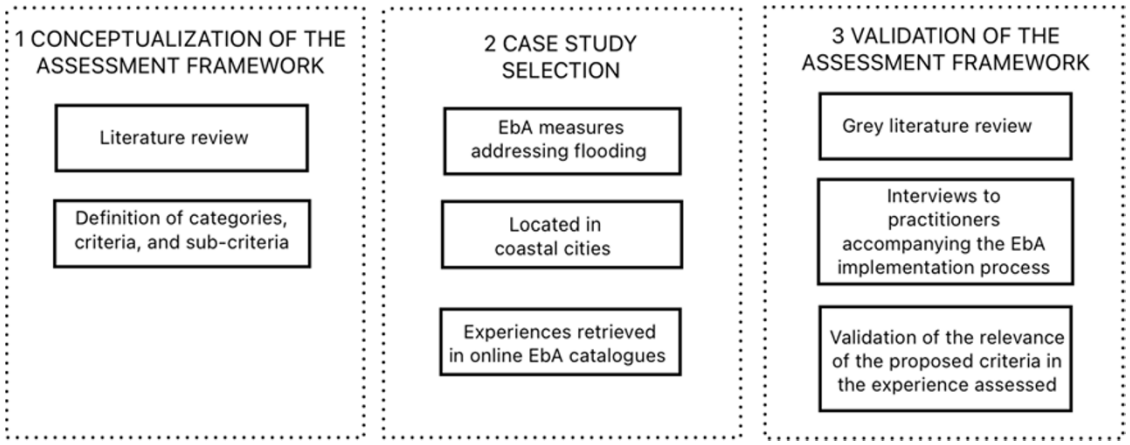

Figure 1. Summary of the methodological process.

planning, etc.) and in-depth interviews with relevant practitioners (see Supplementary Material).

Additionally, seven case studies were included in the assessment after reviewing online EbA catalogues, such as the Urban Nature Atlas[2], OPPLA[3], GeoIKP[4], and the Climate Adapt database[5]. These case studies were selected to further test the framework based on the criteria mentioned above. The EbA experiences included urban farming in the 'Hort del Cànem', the green corridor of 'Passeig Sant Joan', and the introduction of Sustainable Urban Drainage System (SUDS) in the park of Joan Reventós (Barcelona, Spain); a dunes restoration initiative in the Barcelona Metropolitan Area; the Monsanto Green Corridor (Lisbon, Portugal); wetland restoration in the park 'Las Llamas' (Santander, Spain); and the renaturation of Palma beach (Palma, Spain). The assessment was based on the review of grey literature, and direct contact with relevant stakeholders involved in the implementation process of selected interventions, as well as online interviews whenever stakeholders were available.

Based on the information retrieved from the literature review and the interviews, it was assessed whether the criteria and sub-criteria included in the framework were met in the selected case studies. This exercise helps to validate the impact of the selected criteria throughout an EbA implementation process.

4. Results and discussion

Several basic elements are necessary for setting the course for climate change adaptation and the successful implementation of EbA interventions. These include the governance system, as referred, among others, to political support, operational knowledge and scientific expertise, and the involvement of key stakeholders. The adequacy of the policy framework, with non-conflicting regulations, and the availability of sustainable funding are some of the elements discussed next, based on the results of testing the decision-support framework in 10 case studies. Table 2 summarizes the information retrieved from interviews and review of the grey literature of the 10 selected case studies. It indicates which of the selected criteria were met during the EbA implementation process, and which were not.

Building on results reported, aspects such as political support, operational knowledge on EbA, and synergies with future projects are present in nearly all the case studies. In contrast, none of the case studies met the criteria for fiscal incentives, while vertical cooperation was only met in one.

As for the measures that were only assessed for a single study area, there was a clear prevalence of criteria being fulfilled (score = 1) (Table 2). 'Political support', 'Operational knowledge on EbA', 'Source of funding', and 'Regulations' received consistent scores of one across nearly all measures. These could be considered critical success factors when implementing EbA interventions. In contrast, certain criteria may suggest systemic challenges, scoring −1 or 0 in mostly all the measures assessed. These are 'Vertical cooperation', 'Treaties/Agreements', 'Fiscal incentives', and 'Trade-off or disservice'.

When assessing the measures individually, more accurate information was available in those cases where it was possible to interview practitioners. This applies in *Dune restoration* and *Beach renaturation*, which show the most consistent evaluations across all criteria, with very few scores −1 or 0. Both interventions show to have broad institutional backing, to be supported by scientific knowledge and operational experience, and exhibit solid policy frameworks and cooperation mechanisms. In the case of *Dunes restoration*, only 'Scientific knowledge' and 'Treaties/Agreements' are not fulfilled. *Beach renaturation* lacks negative scores, though evidence was not found in the case of 'Trade-off or disservice' and 'Partnerships'. In the assessment of *SUDS in a park*, where no interviewed was conducted, several pieces of information are missing, especially in relation to the policy framework and sustainable funding evaluation.

Wetland restoration was assessed in two study areas, while *Green corridors* in three. The frequency of evaluation of these two EbA across the proposed range of criteria are represented in the figure below (Figure 2). Each cell shows how many times the score (−1, 0, or 1) was assigned to a criterion for each measure. Cells with darker shade show a higher frequency.

As for the mostly repeated criteria across the areas assessed, we found that "Co-creation" was met in all sites assessed (1). 'Scientific knowledge', 'Political support', and 'Synergies' with other projects and initiatives were considered in both *Wetland restoration* and *Green corridors,* suggesting being a widely valued criteria

[2]https://una.city/.
[3]https://oppla.eu/case-study-finder.
[4]https://geoikp.operandum-project.eu/home.
[5]https://climate-adapt.eea.europa.eu/#t-database.

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Table 1. Categories, criteria, and description of the assessment framework

Category	Criteria	Sub-criteria	Description	References
Governance system	Cooperation	Vertical	Inter-governmental cooperation.	Kapos et al. (2019); Matthews et al. (2015); Sarabi et al. (2019)
		Horizontal	Intra-governmental cooperation.	
	Decision-making process	Co-creation process	Understood as a community-based approach which either emerges from, or is supported by, the local actors/key stakeholders.	Albert et al. (2021); Anderson and Renaud (2021); Brink et al. (2016); Cohen-Shacham et al. (2019); Kabisch et al. (2022); Kapos et al. (2019); Nesshöver et al. (2017); Sowińska-Świerkosz and García (2021); Wamsler et al. (2020); Zölch et al. (2018)
		Scientific knowledge	Involvement of scientists to assess the performance of the EbA measure towards extreme events, and the generation of other co-benefits, allowing to reduce uncertainty about its effectiveness.	Davies et al. (2021); Kapos et al. (2019); Nesshöver et al. (2017)
		Political support	Decision inspired by a political decision rather than power relations, such as underlying economic or similar interests for the intervention.	Mell et al. (2022); Seddon et al. (2020)
	Management	Monitoring framework	Analysis of long-term performance, including quantification of co-benefits.	Cohen-Shacham et al. (2019); Geneletti and Zardo (2016); Matthews et al. (2015); Nesshöver et al. (2017)
		Operational knowledge on EbA	Understanding from managers and practitioners about the contribution of the measure to climate change adaptation.	Brink et al. (2016); Matthews et al. (2015)
	Trade-offs/synergies	Synergies	Future plans, or strategies on increasing urban green following the EbA implementation.	Kabisch et al. (2022); Sowińska-Świerkosz and García (2021)
		Trade-off or disservice	Implementation coming at cost of any economic activity/conflicting interests.	Brink et al. (2016); Davies et al. (2021); Dumitru et al. (2020); Kabisch et al. (2022); Seddon et al. (2020)
Policy framework	Plans and strategies		Location and implementation of EbA was part of any EU/national/regional/local plan or strategy.	Esmail et al. (2022); Geneletti and Zardo (2016); Kapos et al. (2019); Kumar et al. (2020); Sowińska-Świerkosz and García (2021)
	Regulations		Existence of non-conflicting regulations, plans, sectoral policies that hinder the uptake of EbA.	Albert et al. (2021); Seddon et al. (2020)
	Treaties/Agreements		Existence of any global (international) or bilateral (national) treaty to frame the EbA implementation.	Albert et al. (2021); Baravikova (2020)
Funding model	Source of funding (EU)		Funding resources with EU origin (grant, subsidy, etc.).	Toxopeus and Polzin (2021)
	Budget structure		Growing amount allocated for EbA maintenance.	Niki et al. (2017); Kapos et al. (2019); Seddon et al. (2020)
	Fiscal incentives		Examples include the reduction of municipal fees or ecological fiscal transfers to promote EbA implementation.	Albert et al. (2021); Kumar et al. (2020); Sarabi et al. (2019)
	Partnerships		Less conventional forms of capital coming from partnerships from different entities (e.g., public, private bodies, NGOs, etc.) to fund the implementation of EbA.	Brink et al. (2016); Sarabi et al. (2019); Seddon et al. (2020); van Ham and Klimmek (2017)

Table 2. EbA measures assessed with the decision-support framework

City/Area			Barcelona[a]	Barcelona[a]	Barcelona[b]	Barcelona Metropolitan Area[b]	Vilanova i la Geltrú[b]	Palma[b]	Benidorm[b]	Santander[a]	Lisbon[a]	Oeiras[b]
Name of the intervention assessed			SUDS[1] in a park	Green corridor	Urban farming	Dunes restoration	Wetland restoration	Beach renaturation	Riparian reforestation	Wetland restoration in a park	Green corridor	Green corridor
Category	Criteria	Subcriteria										
Governance system	Cooperation	Vertical (inter-governmental)	0	0	0	−1	−1	0	1	−1	0	−1
		Horizontal (intra-governmental)	−1	0	−1	1	1	1	1	0	0	1
	Decision-making process	Co-creation	−1	−1	1	1	1	1	−1	1	1	−1
		Scientific knowledge	1	0	−1	−1	1	1	−1	0	1	1
		Political support	1	1	−1	1	1	1	1	1	0	1
	Management	Monitoring framework	0	0	−1	1	−1	1	−1	0	1	−1
		Operational knowledge on EbA	1	0	1	1	1	1	1	0	0	1
	Trade-offs/synergies	Synergies	1	1	1	1	1	1	−1	1	0	1
		Trade-off or disservice	0	0	0	1	1	0	−1	1	0	−1
Policy framework	Plans and strategies		0	1	−1	1	1	1	1	0	1	1
	Regulations		0	0	1	1	1	1	1	0	0	1
	Treaties/Agreements		0	0	−1	−1	−1	1	−1	0	1	1
Funding model	Source of funding (EU)		0	0	−1	1	1	1	−1	0	−1	1
	Budget structure (increasing)		0	0	0	1	1	1	1	0	0	1
	Fiscal incentives		0	0	−1	−1	−1	−1	−1	0	0	−1
	Partnerships		0	0	1	1	1	0	−1	1	0	1

Source:
[a]*Information obtained from grey literature review*
[b]*information obtained from grey literature review and interviews.*
Legend: ***1*** *indicates that the criterion is fulfilled; −1 indicates the criterion is not fulfilled;* ***o*** *indicates that no evidence was found to validate the accomplishment of the criteria.*
[1]*Sustainable Urban Drainage Systems*

		Green corridors (n=3)			Wetland restoration (n=2)		
Assessment framework criteria / Fulfilment-based labels		Fulfilled	Insufficient evidence	Not fulfilled	Fulfilled	Insufficient evidence	Not fulfilled
Governance system	Vertical (cooperation)	0	2	1	0	0	2
	Horizontal (cooperation)	1	2	0	1	1	0
	Co-creation	0	0	3	2	0	0
	Scientific knowledge	2	1	0	1	1	0
	Political support	2	1	0	2	0	0
	Monitoring framework	1	1	1	0	1	1
	Operational knowledge on EbA	1	2	0	1	1	0
	Synergies	2	1	0	2	0	0
	Trade-off or disservice	0	2	1	2	0	0
Policy framework	Plans and strategies	3	0	0	1	1	0
	Regulations	1	2	0	1	1	0
	Treaties/Agreements	2	1	0	0	1	1
Funding model	Source of funding	1	1	1	1	1	0
	Budget structure	1	2	0	1	1	0
	Fiscal incentives	0	2	1	0	1	1
	Partnerships	1	2	0	2	0	0

Figure 2. Green corridors and wetland restoration. Frequencies per criteria.

in both contexts. 'Institutional cooperation' was either not fulfilled or with insufficient evidence, indicating broader necessary efforts in institutional cooperation.

There was a divergent assessment in both 'Monitoring framework' and 'Operational knowledge on EbA' with scores ranging from −1 to 1. This could be explained either due to context-specific performance or differing stakeholder views. 'Trade-off or disservice' received moderate frequencies at all scores.

Further analysis and discussion of the results are provided in the following subsections.

4.1. Influence of the governance system on the implementation of EbA

EbA implementation involves multiple steps and actors, crossing jurisdictional boundaries. The corresponding decision-making processes might range from urban-drainage systems managed at the local level, watershed restoration managed regionally, to wetland restitution involving national authorities. Government cooperation occurs both horizontally (within the same institution and/or same governance level) and vertically (among institutions at different scales). This cooperation is necessary to implement any intervention (Kapos et al., 2019; Leone, 2021) as competences might be distributed across different governing bodies and/or different departments involved in the decision and implementation process.

The natural setting of each area shapes not only the types of measures implemented but also their governance complexity. For instance, riverine restoration projects (Benidorm) involve different actors and jurisdictional scales than coastal dune rehabilitation (Barcelona Metropolitan Area), or urban green infrastructure (Oeiras). City council departments usually serve as primary planners for climate change adaptation, setting up a wide range of interventions that affect the well-being of the inhabitants. Based on the assessed examples, horizontal cooperation within the same institution has proven effective in small and medium-sized city councils, as demonstrated by the case studies of Palma, Benidorm, Vilanova i la Geltrú, and Oeiras. However, bureaucracy and protocols increase with the size of the institution, hindering the decision-making process and lengthening the implementation process as it was observed in all case studies from the city of Barcelona.

EbA projects very often involve natural restoration efforts that extend beyond municipal boundaries. Therefore, cooperation among neighbouring municipalities is essential, as these projects cannot be confined to a single municipality. This is the case of the green corridor "Eixo Verde e Azul" in Oeiras, where the neighbouring municipalities of Sintra, Amadora, and Oeiras have agreed to cooperate on restoring and naturalising the Jamor River. The main objectives of this initiative were to reduce flooding, enhance recreational opportunities, ensure accessibility, and establish green connectivity along the 16-km length of the river.

In terms of vertical cooperation, the responsibility for restoring a natural area can be shared between local (e.g., land ownership, security) and regional administrations (e.g., maintenance competence, regulations). These competences are often transferred to the

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local or metropolitan level, as they might be better able to apply for the necessary funding (Santander, Benidorm, Vilanova i la Geltrú, Barcelona Metropolitan Area). Nevertheless, the high bureaucracy involved in obtaining the necessary permits from supra-municipal departments delays and hinders the process (Vilanova i la Geltrú, Santander, Barcelona Metropolitan Area, Oeiras). Standardizing and simplifying the application process will contribute to the uptake of EbA. Both vertical and horizontal cooperation are important for strengthening the governance system and ensuring the effective implementation of EbA.

The implementation of any measure is preceded by a decision-making process whose factors will influence the outcome. These include, among others, co-creation, scientific knowledge, and political support. Engaging influential individuals is key to boost local social networks and increasing the legitimacy of the proposed measures (Kabisch et al., 2022; Sowińska-Świerkosz & García, 2021). Evidence from the assessed interventions indicates that involving citizens in the process enhances acceptance and deepens understanding of the benefits and adaptation implications of the proposed measures (Santander, Barcelona Metropolitan Area). In some situations, the implementation of EbA responds to citizens' demand (Barcelona – Hort del Cànem, Vilanova i la Geltrú). Bottom-up approaches enable the uptake of EbA by encouraging decision-makers to prioritise co-creation, leading to more widely accepted interventions. Projects that fostered co-creation and included scientific bodies and local actors in the design and implementation process (Vilanova i la Geltrú, Palma, Lisbon), strengthened multi-actor collaboration, and appear to be a key differentiator, even within the same geographical context (Oeiras, Barcelona–Passeig de Sant Joan).

Academic and scientific organisations share their expertise to inform decision-makers with the latest scientific developments (Davies et al., 2021; Kapos et al., 2019; Nesshöver et al., 2017). Providing this support to city council planners, technicians and other local stakeholders – who often lack research capacity – is essential for gaining knowledge on topics such as climate change projections, hazard risk modelling, and the socioeconomic impact of potential adaptation measures and strategies. Based on our assessment, whenever there are climate and environmental reports to support the need for intervention, successful implementation results were found, as demonstrated in the case studies of Oeiras, Lisbon, Palma, Barcelona–SUDS, and Vilanova i la Geltrú. Both in Oeiras and Lisbon, researchers from local universities assisted the technical reports informing on flooding hazards of the areas under intervention and the convenience of transforming the landscape into a permeable green area. A similar situation occurred in Barcelona and Vilanova i la Geltrú. Addressing scientific challenges related to climate uncertainty, biodiversity dynamics in response to main threats, and the design of future scenarios requires a comprehensive assessment. This can be achieved through effective monitoring frameworks and the development of robust governance strategies (Hossaert & Le Roux, 2023).

When political support for the proposed intervention exists, it reflects a strong commitment to adaptation, initiated and sustained by city officials with local leadership and influence (Zölch et al., 2018). On the contrary, the lack of political support can be a barrier to EbA implementation, alongside the absence of financial resources and conflicting regulations (Duffaut et al., 2022). In all but one of the case studies with information available, the decision was political. In two situations, it was initially led by the community (Barcelona–Hort del Cànem; Vilanova i la Geltrú) before being embraced by local institutions. Political support is thus revealed as an enabler for EbA implementation, showing strong support in all situations under study.

Successful management of interventions is highly related to the existence of a monitoring framework (Cohen-Shacham et al., 2019; Geneletti & Zardo, 2016; Nesshöver et al., 2017), operational knowledge related to the multiple co-benefits EbA measures provide (Anderson & Renaud, 2021; Kabisch et al., 2022; Mell et al., 2022) and know-how related to the rules, operations and relationships with external actors involved in the adaptation efforts. Lisbon, Palma, and Barcelona Metropolitan Area track the performance of the assessed EbA measures, while know-how on EbA is present in all cases interviewed, overcoming a frequent barrier in ecosystem management practices (Brink et al., 2016). In-house technical knowledge on adaptation and the additional benefits of these measures drives EbA implementation as an alternative to other engineered-based infrastructures.

Two assessed interventions (Las Llamas–Santander; Parc Joan Reventós–Barcelona) were pioneering in inspiring future SUDS interventions across Spain. Other projects inspired the development of further urban green corridors (Sant Joan–Barcelona), promoted dunes restoration interventions along the Metropolitan Area of Barcelona shoreline, as well as river restoration with additional recreational purposes (Oeiras). As recalled by Dumitru et al. (2020), balancing and mapping the synergies and trade-offs of EbA projects contribute to their uptake. Trade-offs are not necessarily negative, especially when the restoration of natural capital is enhanced. In some cases, urban development may result in allocating less space for housing and other uses, allowing to increase biodiversity and recreational areas (Santander) or to restore a wetland (Vilanova i la Geltrú). Moreover, decisions may lead to the reduction of beach area designated for recreational activities, favouring dunes restoration and coastal erosion mitigation (Barcelona Metropolitan Area).

4.2. *Influence of the policy framework in the implementation of EbA*

Failing to explicitly mention EbA in plans and strategies can hinder their implementation (Geneletti & Zardo, 2016). Integrating EbA interventions into climate change plans (Lisbon, Oeiras, Barcelona Metropolitan Area, Benidorm, Vilanova i la Geltrú) as well as other strategies promoting biodiversity, enhances green infrastructure in urban areas (Palma; green corridor – Barcelona). These documents ensure that spatial planning is adequate for the proper implementation and management of EbA (Sowińska-Świerkosz & García, 2021), thereby reducing the vulnerability of human and natural systems to climate change. Based on the research conducted, the existence of climate change plans and strategies enable the implementation of these measures, increasing urban climate resilience.

Plans provide clear guidance and reduce bureaucratic obstacles, leading to harmonious top-down regulations that avoid conflicts, for instance, between urban planning and environmental regulations, which might hinder EbA implementation (Seddon et al., 2020). Evidence of these benefits have been observed in the cases assessed (Barcelona Metropolitan Area, Barcelona, Palma, Oeiras, Vilanova i la Geltrú, and Benidorm) resulting in positive long-term additional benefits (Niki et al., 2017), such as carbon capture, biodiversity improvement, or increase of recreational opportunities, among others.

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Including green infrastructures into regulations helps shifting traditional approaches, which often rely on grey engineering solutions. This change reflects the growing interest among practitioners and policy makers in adaptation. Embedding EbA interventions into existing policies demonstrates institutional recognition of their importance in addressing climate change. It highlights the role these interventions play in adapting urban areas and rises awareness on the ecosystem services and additional benefits they provide. This is the case of the interventions undertaken in Barcelona Metropolitan Area, Palma, Barcelona (Urban Farming), Oeiras, Vilanova i la Geltrú, and Benidorm, where all the applying norms and regulations were aligned and did not interfere with each other, making it easier to ask for the necessary intervention permits.

Some examples of local regulations alignment are the Open spaces and Sustainable drainage regulations with the beach renaturation in Palma. Actions proposed do not interfere with the aims and principles included in both regulations, such as the promotion of leisure activities in open spaces or the inclusion of permeable pavements and similar interventions to reduce impervious surface in floodable prone areas. In Vilanova i la Geltrú, the wetland restoration project was supported by the Special Plan, which was aligned with the urbanism city council department's recognition of the site as a green area.

The transition to greener cities is driven by international treaties, guiding the inclusion of environmental principles in downscale regulations (Baravikova, 2020). European Directives or strategies, such as the Green Deal or the Biodiversity Strategy to 2030 contribute to align and set the priorities at local scale. These international agreements shape adaptation interventions, such as the United Nations Sustainable Development Goals (SDG) (Palma, Benidorm) or support key objectives of the EU2020 strategy (Oeiras), facilitating their effective implementation at the local level.

The green corridor (Eixo Verde e Azul) in Oeiras was framed within the Biodiversity Strategy to 2030, which inspired the design of the specific interventions to implement in the area. Similarly, this initiative was also aligned with the objective of the EU2020 strategy of reducing greenhouse emissions. Former initiatives, such as the white paper '*Adapting to climate change: towards an European framework for action*', which inspired the EU2020 strategy, also led to interventions like the green corridor in Lisbon. This document advocated for a significantly increase in activities related to climate change adaptation, and was incorporated into the Portuguese National Strategy for Adaptation Climate Disturbances (2010). In the case of Palma and Benidorm, the interventions proposed are aligned with the following SDGs: 'Clean water and sanitation', 'Sustainable cities and communities', and 'Climate Action'. Additionally, Palma's beach renaturation project is aligned with the SDG of 'Life below water goal'.

4.3. Influence of the funding model in the implementation of EbA

Limited funding opportunities for EbA implementation are widely recognised as a barrier to scaling up these measures (Sarabi et al., 2019). International programmes and institutions, such as Horizon Europe from the European Commission, or the European Regional Development Fund, have been designed to finance research and development cooperation to strengthen economic, social, and territorial cohesion. Very often EbA implementation requires huge financial efforts which are not possible to undertake under limited local budgets. Access to EU funds managed locally has opened opportunities to increase the number of adaptation projects (Barcelona Metropolitan Area, Palma, Oeiras, Vilanova i la Geltrú). Local resources also play a central role in the co-funding of these initiatives, ensuring their long-term sustainability (Lisbon, Oeiras, Vilanova i la Geltrú, Benidorm). Self-managed initiatives are rare but can offer a viable option when organised groups of committed citizens work towards transforming cities into greener and more liveable spaces. This was the case of the urban farming project in Barcelona, where in the early stages of the project residents organised themselves to transform an abandoned plot into an urban farming initiative. In addition to their personal dedication, crow funding initiatives contributed to fund gardening tools and related materials necessary to set up the orchard.

The composition of a local budget reflects the policy objectives, while its size is related to the dimension of the municipality. The allocation of resources for EbA interventions demonstrates a clear interest by institutions to integrate EbA into local planning. During this research, it was not possible to access and analyse the local budget structures of the municipalities under study. However, evidence from the interviews suggests growing efforts by local institutions to adapt to climate change by increasing the budget of environmental related departments (Barcelona Metropolitan Area, Palma, Benidorm, Oeiras). All case studies reported that the amount invested in these interventions varies with resource availability. When high budgets are available, there is a clear intention to increase the number of these interventions through its co-funding with local and external sources, such as EU funds. Practitioners confirmed that maintenance costs decrease once the intervention is well established (Barcelona Metropolitan Area, Oeiras, Vilanova i la Geltrú). Nevertheless, significant maintenance or even partial restoration investments will be required after extreme events such as severe storms and flooding.

The need for economic and financial resources sourced from diverse institutions involves exploring innovative mechanisms (Seddon et al., 2020). To promote the adoption of EbA, fiscal incentives – such as the reduction of municipal fees or ecological fiscal transfers – can be made conditional upon their implementation and the achievement of specific performance indicators (Albert et al., 2021; Kumar et al., 2020; Seddon et al., 2020). Ecological fiscal transfers can serve as an alternative funding source for EbA interventions, particularly when the financial resources are managed locally. Different situations have been identified in the assessed case studies. Although none of them currently implement these innovative mechanisms, the interviewed Spanish practitioners in Vilanova i la Geltrú, Palma, Benidorm, and Oeiras showed a high interest in exploring these options. However, based on the interviews conducted for the Portuguese case studies, these mechanisms are not viable options for the Portuguese municipalities, as most taxes are collected at the national level. Promoting local tax management and fiscal transfers to municipal scale can be a great opportunity for EbA upscale.

Cooperation between private and public bodies offer a great opportunity to fund and upscale EbA interventions (Toxopeus & Polzin, 2021; van Ham & Klimmek, 2017). One example documented in the case studies is the urban farming project in Barcelona, where hotel promoters were asked to finance the redevelopment of the surrounding area, including the urban farming settlement. Nonetheless, this and similar experiences reported in Benidorm and Palma, may fail to invest in other areas of the city where EbA implementation is needed to restore natural values

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disrupted by urbanisation. There is potential to further explore PPP to upscale of EbA interventions, as they constitute an additional source to fund initiatives that the municipalities might not be able to support on its own.

NGOs can play an important role in the promotion of EbA. They may support advocacy, promote dialogue on adaptation, support monitoring programmes, and facilitate knowledge exchange, while also providing an alternative source of funding. The collaboration between these institutions and the municipalities is showcased in various case studies. For instance, the involvement of NGOs in monitoring bird communities in Las Llamas Park (Santander), revegetating the restored wetland in Platja Llarga (Vilanova i la Geltrú), and conducting outreach activities in Oeiras. Moreover, the case studies of Barcelona Metropolitan Area and Vilanova i la Geltrú highlighted the involvement of private sector entities in the cleaning and maintenance activities of EbA interventions as part of its corporate social responsibility strategy.

5. Conclusions

Although EbA, along with NbS, is increasingly recognised at the EU level, their implementation in urban contexts is still limited. This research focuses on EbA implementation processes in coastal urban areas and develops a decision-support framework to facilitate local-level adoption in these contexts. The framework assesses the enabling conditions that influence the implementation of EbA, focusing on governance systems, policy frameworks, and funding models. While the empirical findings provide valuable insights into specific coastal urban case studies of Spain and Portugal, the broader contribution of this research lies in the framework capacity to assist local decision makers and practitioners through the implementation of EbA measures and strategies across diverse contexts.

The results of this research suggest that local scale is the optimal level to operate EbA interventions, as there is better knowledge of the adaptation needs and institutions are closer to citizens, allowing for effective co-creative processes. However, local-level implementation remains limited to governance challenges, policy misalignments, funding, and financial limitations.

Misalignments between different administrative levels, and bureaucracy hinder the implementation process of EbA. To overcome these challenges, it is important to adopt interdisciplinary approaches and enhance capacity building and policy support. Adaptive and flexible governance structures are necessary to ensure the integration of EbA in local planning and their sustainability. Vertical and horizontal cooperation amongst institutions would contribute to improve the necessary cooperation and communication, protocols and plans to articulate the processes and avoid conflicting regulations.

Increasing our understanding of the potential benefits and drawbacks of EbA, as well as the creation of systematic guidance for policymakers, are central for successful implementation experiences. For long-term performance and EbA uptake, monitoring frameworks and knowledge dissemination will help to reduce uncertainties and promote EbA replication. The formulation of this framework responds to a growing demand within the global scientific and policy communities for integrative tools that can bridge the knowledge gap between EbA planning and practice. Its structure – grounded in institutional, technical, and socio-political dimensions – allows researchers, practitioners, and decision-makers to identify enablers and barriers to implementation in consistent and replicable manner.

This study emphasises the importance of addressing governance and financial challenges, to scale up EbA interventions, and contribute to adaptation and urban resilience. Embedding EbA in local and regional adaptation plans and strategies is central to address environmental challenges more effectively. Securing diverse and sustainable funding sources is key for an effective EbA implementation. Innovative funding mechanisms, such as fiscal incentives and PPP, together with stable or growing budget allocations, can further support the overcoming financial barriers and long-term benefits.

This framework has been developed under coastal urban contexts mainly affected by flooding episodes, but it was designed to be adaptable. Future research in this field could consider the application of this framework across geographies, governance levels, and scales of intervention, making it a valuable instrument for cross-case comparisons, long-term monitoring, and policy learning. This assessment will help to have a better evaluation of EbA and support evidence-based planning.

This research offers a methodological contribution with the potential to inform future comparative studies and research within the field of climate adaptation. It lays the foundation for building cumulative knowledge on enabling conditions for EbA, encouraging both critical reflection and harmonisation in assessment approaches across the scientific community.

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