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D7.1-Synthesis of socio-economic assessment methods, databases, and studies addressing EBA and other adaptation strategies

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AUTHOR(S) – Mar Riera Spiegelhalder (ENT), Luís Campos Rodrigues (ENT), Janneke den Dekker-Arlain (IHS), Elena Marie Enseñado (IHS), Elina Makousiari (IHS) , Stratos Arampatzis (TERO), Olympia Papadopoulou (TERO), Iason Tamiakis (TERO), Koen Vervoort (ENoLL), Marta De Los Ríos White (ENoLL), Salem Gharbia (ITSligo), Iulia Anton (ITSligo), Ananya Tiwari (ITSligo).

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LIST OF ACRONYMS AND ABBREVIATIONS

Acronym / Abbreviation	Meaning / Full text
AHP	Analytic Hierarchy Process
BBN	Bayesian Belief Networks
CBA	Cost-Benefit Analysis
CCLL	Coastal City Living Lab
CEA	Cost-Effectiveness Analysis
CICES	Common International Classification of Ecosystem Services
COMASO	Coastal Management Software
CORDIS	Community Research and Development Information Service
CVM	Contingent valuation method
DESSIN	Demonstrate Ecosystem Services Enabling Innovations in the Water Sector
EAD	Expected Annual Damage
EBA	Ecosystem-based Approach
EEA	European Environment Agency
GHG	Greenhouse Gas
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
IUCN	International Union for Conservation of Nature
LRA	Literature Review Analysis
MCA	Multi-Criteria Analysis
MEA	Millennium Ecosystem Assessment
NBS	Nature-based solutions
NPV	Net Present Value
NUTS	Nomenclature of Territorial Units for Statistics

Acronym / Abbreviation	Meaning / Full text
OUDS	Open Urban Drainage Systems
PRISMA	Preferred Reporting Items for Systematic Reviews and Meta-Analysis
RPO	Research Performing Organisation
ROA	Real Options Analysis
SCBA	Social Cost-Benefit Analysis
SDG	Sustainability Development Goals
SIS	Sustainability Impact Score
SLR	Sea Level Rise
SME	Small Medium-sized Enterprises
SWI	Saltwater Intrusion
SWOT	Strengths, Weaknesses, Opportunities, Threats
UK	United Kingdom
UNFCCC	United Nations Framework Convention on Climate Change
USA	United States of America
WoS	Web of Science
WTA	Willingness to accept compensation
WTP	Willingness to pay

BACKGROUND: ABOUT THE SCORE PROJECT

SCORE is a four-year EU-funded project aiming to increase climate resilience in European coastal cities.

The intensification of extreme weather events, coastal erosion and sea-level rise are major challenges to be urgently addressed by European coastal cities. The science behind these disruptive phenomena is complex, and advancing climate resilience requires progress in data acquisition, forecasting, and understanding of the potential risks and impacts for real-scenario interventions. The Ecosystem-Based Approach (EBA) supported by smart technologies has potential to increase climate resilience of European coastal cities; however, it is not yet adequately understood and coordinated at European level.

SCORE outlines a co-creation strategy, developed via a network of 10 coastal city 'living labs' (CCLLs), to rapidly, equitably and sustainably enhance coastal city climate resilience through EBA and sophisticated digital technologies.

The 10 CCLL involved in the project are: Sligo and Dublin, Ireland; Barcelona/Vilanova i la Geltrú, Benidorm and Basque Country, Spain; Oeiras, Portugal; Massa, Italy; Koper, Slovenia; Gdansk, Poland; Samsun, Turkey.

SCORE will establish an integrated coastal zone management framework for strengthening EBA and smart coastal city policies, creating European leadership in coastal city climate change adaptation in line with The Paris Agreement. It will provide innovative platforms to empower stakeholders' deployment of EBA to increase climate resilience, business opportunities and financial sustainability of coastal cities.

The SCORE interdisciplinary team consists of 28 world-leading organisations from academia, local authorities, RPOs, and SMEs encompassing a wide range of skills including environmental science and policy, climate modelling, citizen and social science, data management, coastal management and engineering, security and technological aspects of smart sensing research.

EXECUTIVE SUMMARY

This document is a deliverable of the SCORE project, funded under the European Union's Horizon 2020 research and innovation programme under grant agreement No 101003534.

The aim of this document is to present the results of a systematic literature review of studies performing socio-economic assessments of climate change adaptation in coastal areas. This analysis is preceded in the current deliverable by an introductory contextualization of climate change impact and adaptation in coastal areas; an explanation of the concept of ecosystem-based approach (EBA) in relation to soft and hard-based measures; and an overview of socio-economic and environmental valuation and assessment approaches.

The systematic literature review followed PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analysis) 2020 methodology to ensure consistency and quality of the results. A total of 6,501 records were initially identified. After excluding duplicates, and studies not fulfilling eligibility criteria, 51 studies were finally included in the literature review analysis. Studies were characterized in terms of its basic information (e.g., year of publication, type of publication), socio-economic assessment methods (e.g., name of the method, timing of the assessment, stakeholders' involvement), adaptation context (e.g., type of adaptation measures addressed, climate change impact considered in the studies), metrics (e.g., monetary, and non-monetary metrics applied), and performance (e.g., main quantitative and qualitative results of the assessments, policy recommendations provided).

From the 51 studies reviewed, 23 were cost-benefit analysis (CBA), six performed multicriteria analysis (MCA), three combined MCA and CBA, two developed a CBA and cost-effectiveness analysis (CEA), and the remaining 17 felt under the category of 'other' types of methods (e.g., real-option analysis - ROA; economic impact evaluation, and risk assessment). Amongst the main results, the review revealed that most of the selected studies addressed hybrid adaptation strategies, i.e., a mixed bundle of solutions (hard, soft or EBA). From these, hard measures such as dike constructions and seawalls were often considered for flooding and sea-level rise (SLR); soft-based actions like beach nourishment were at times presented as potential cost-effective measures to mitigate coastal erosion and flooding; and EBA relying on the regeneration of coastal ecosystems (e.g., mangrove forests, reefs, wetlands), or the implementation of green infrastructure options such as porous pavements or the expansion of green urban areas were sometimes considered for the mitigation of extreme heat events and flood run-off, along with other impacts.

LINKS WITH OTHER PROJECT ACTIVITIES

This deliverable supports the development of the remaining tasks of WP7. The improved knowledge about assessment methods gained with this literature review will directly benefit Task 7.2. – "Development of a framework for the socio-economic assessment of adaptation measures to climate change". This task includes the development of methodology for a participatory assessment (partial analysis) to be implemented in Task 7.3 to all coastal city living labs (CCLLs), involving their local and regional stakeholders in the evaluation, comparison, and prioritisation of different interventions. Moreover, a methodology will be developed for a combined participatory and expert-based assessment (full analysis) to be undertaken in Task 7.4 in frontrunner CCLLs. This analysis will provide a comprehensive assessment of the financial costs and benefits of EBA, as well as of their impact in terms of ecosystem. Task 7.5 - which aims to formulate a set of policy recommendations to assist decision making in climate change adaptation at the local, national and EU level - will also benefit from the insights obtained from the reviewed studies in terms of their policy recommendations.

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INTRODUCTION

1.1. Objectives and outline of the deliverable

This deliverable aims to summarise the work developed in Task 7.1 - "Analysis of socio-economic assessment methods, databases, and studies addressing EBA and other adaptation strategies". This report is structured as follows. The remaining subsections of this introductory chapter will present several key concepts and methods that will support the development of this task and of WP7 work in general. This involves contextualising the impact of, and adaptation to, climate change in coastal areas; introducing the concept of Ecosystem-based Approaches (EBA) and establishing its comparison with other types of adaptation strategies; and outlining socio-economic and environmental valuation and assessment approaches. This latter objective includes the presentation of the concept of total economic value (TEV), which groups a wide set of values of environmental resources; a synthesis of standard environmental valuation methods; and the conceptualization of ecosystem services and further overview of some multi-ecosystem services evaluation tools. Section 2 is the main core of this deliverable, which focus on a systematic literature review of socio-economic assessment studies applied to climate change adaptation in coastal. Section 3 will present the main conclusions of this report.

1.2. Contextualizing climate change in urban coastal areas

The effects of climate change on both human and natural systems result in loss and damage to ecosystems, infrastructure, environment, and populations worldwide. Coastal areas, where patterns of human settlements traditionally emerge, face sea-level rise, coastal flooding, erosion, and salination, among other hazards (Doust et al., 2021; Oppenheimer et al., 2019; Neumann et al., 2015). These coastal hazards and associated impacts have compounding consequences to society and the economy. With that, climate change adaptation – alongside climate change mitigation – is a necessary response. According to the Intergovernmental Panel on Climate Change (IPCC) adaptation can be defined as the "process of adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities" (IPCC, 2014). Indeed, the goal of adaptation is to enhance adaptive capacity, strengthen resilience, and reduce vulnerability (UNFCCC, 2015).

Adaptation, which depends on specific geographical, institutional, social, and economic local contexts and conditions, can be anticipatory or reactive (Klein, 2003); planned or autonomous (Carter, 1994); incremental or transformational (IPCC, 2014). Adaptation can also depend on the timing as well as the purpose of its implementation; on the system in which adaptation takes place; and on whether these are driven by public or private interests. Depending on the time and purpose, adaptation can be reactive (which happens once the initial climate change impacts have been evident) or proactive or anticipatory (which occurs even before impacts manifest) (Klein, 2003).

Adaptation also depends on whether it takes place in human (both reactive and proactive) or natural systems (reactive) (Klein, 2003; Rusinga et al., 2014). In human systems, adaptation is driven by private (e.g., individual households and companies) and/or public interests (e.g., different government levels). Whether driven by private or public interests, adaptation can be planned, as a result of a deliberate policy decision, or autonomous, which can be

motivated by self-interest. Recently, adaptation has been considered either incremental or transformational. Incremental adaptation aims to maintain the essence and integrity of a system or process at a given scale, while transformational adaptation changes the fundamental attributes of a system in response to climate and its effects (IPCC, 2014).

Climate change adaptation covers several actions, ranging from social and institutional to physical and structural ones (IPCC, 2014). For instance, social adaptation refers to educational, informational, and behavioural actions, such as awareness-raising, early warning and response systems, household evacuation, retreat, and migration; while institutional adaptation encompasses economic options (e.g., insurance, subsidies, taxes), laws and regulations (e.g., water regulation agreements, land assessments and zoning), and policies and programmes (e.g., adaptation plans, mainstreaming). Physical and structural adaptation activities include engineered and built environments (e.g., coastal protection, flood and cyclone shelters, storm drainage, and wastewater management), technological innovation (information and communication technology, traditional technologies), services (e.g., emergency and health services, social safety nets), and ecosystem-based adaptations or EBA.

Several authors make the distinction between different types of adaptation measures. The analysis presented in this deliverable aligns with the following classification (**Table 1**):

1) Hard measures – these refer to physical interventions, often in the form of engineering-based solutions (Bloetscher et al., 2016) "that can withstand climatic variability and extremes (e.g., levees, technical shading, irrigation systems)" (Zölch et al., 2018). Dikes, seawalls, or breakwaters are frequently used measures to prevent or contain hazards, such as flooding or sea-level rise (SLR).

2) Soft measures – initiatives aimed at encouraging adaptative behaviour (Zölch et al., 2018), awareness raising and institutional capacity building (Jones et al., 2012), or strategies to strengthen building codes in the form of wet-proofing, dry-proofing, and building elevation (Aerts et al., 2014; de Ruig et al., 2019; Scussolini et al., 2017). Government actions are intended to outweigh negative effects of climate change by adapting policies, urban and land use planning instruments, or even subsidizing vulnerable citizens groups to mitigate climate hazards as extreme heat events, SLR, coastal erosion or intense precipitations, among others.

3) EBA – Ecosystem-based Approach includes adaptation interventions implemented at the ecosystem level, ecological structure, functions, and services provided (Wamsler et al., 2016). Shadowing streets, green roofs or parks aimed at reducing climate risk are some of the adaptation measures considered in this category. The adaptation to climate change is based on green infrastructure interventions, ensuring ecosystem service provision, and preserving and promoting biodiversity.

4) Hybrid – this category is applied when there is a combination of the previous adaptation options. Proposed adaptation strategies then, can be a set of hard and soft measures, seawall construction and beach nourishment (Andreadis et al., 2021), dike construction and planning (Haer et al., 2017), a combination of soft and EBA measures, permeable pavements, and green roofs (Locatelli et al., 2020), but also a mix of hard, soft and hybrid strategies (André et al., 2016).

Table 1: Types of adaptation measures

Typology	Aim	Examples of adaptation measures
Hard	Prevent or contain hazards.	Levees, dikes, seawalls, breakwaters.
Soft	Encourage adaptative behaviour.	Strengthen building codes, land use planning instruments, subsidies.
EBA	Ensure ecosystem service provision and preserve and promote biodiversity.	Trees planting in streets, green roofs, increase of green urban areas.
Hybrid	Combination of the previous adaptation options.	Dike construction and planning; permeable pavements and green roofs.

Source: Own elaboration.

1.3. Introducing the concept of EBA for urban coastal areas

EBA first emerged in 2008 during the United Nations Framework Convention for Climate Change (UNFCCC) (Wertz-Kanounnikoff et al., 2011). At first, the concept was applied in the global south, but it is now widely recognised as a valid concept and related methodology for both developing and developed countries (Vignola et al., 2009; Brink et al., 2016). Even the European Union (EU) climate adaptation strategy encourages EBA's implementation in urban management (European Commission, 2013a). EBA refer to ''an integrative approach combining biodiversity and ecosystem services within climate change adaptation planning to promote urban capacities to adapt to climate change" (adapted from the Secretariat of the Convention on Biological Diversity, 2009). Alternatively, EBA refer to practices that promote socio-ecological resilience by fostering ecosystem services, through ecosystem management that enable people to adapt to the impacts of climate change and reduce their vulnerability (Ojea, 2015). The focus relates to sustainable management, conservation, and restoration of ecosystems with the objective to provide services supporting human's adaptation to climate change along with social, economic, and cultural co-benefits for local communities (Secretariat of the Convention on Biological Diversity, 2009; Munang et al., 2013). This concept has been applied in agricultural and forestry sectors (Doswald et al., 2014; Vignola et al., 2009), while in urban areas, the interest in EBA as a cost-effective, comprehensive multi-functional approach is rising (Brink et al., 2016). In cities, EBA refer to the use of urban ecosystems providing ecosystem services which benefit climate adaptation (Geneletti and Zardo, 2016).

Recently, EBA – alongside other related concepts, such as green infrastructure and ecosystem services, have been categorized under the umbrella term of nature-based solutions or NBS (Nesshöver et al., 2017; Pauleit et al., 2017; Naumann et al., 2011). NBS was introduced by the World Bank and the International Union for Conservation of Nature (IUCN) towards the end of the 2000s to emphasize the importance of biodiversity conservation for climate change mitigation and adaptation (Cohen-Shacham et al., 2019). NBS refer to actions which protect, sustainably manage, or restore natural or modified ecosystems, whilst simultaneously addressing societal challenges and providing human well-being and biodiversity benefits (Cohen-Shacham et al., 2016). NBS have been defined by the European Commission as "actions which are inspired by, supported by or copied by nature" (European Commission, 2013b; European Commission, 2015). With nature-inspired actions, NBS not only explicitly link biodiversity

conservation goals but also sustainable and climate-resilient development goals (Eggermont et al., 2015). Moreover, NBS refer to effective and feasible solutions, with benefits ranging from environmental protection to job creation.

The implementation of EBA and the realisation of their solutions, encourage the proliferation of the transition to a resource-efficient and socially-inclusive sustainable economy. The concept has also been adopted by the European Commission for its research programme Horizon 2020 (European Commission, 2013b; European Commission, 2015). Within Horizon 2020, NBS are defined as '' any transition using ecosystem services with decreased input of non-renewable natural capital and increased investment in renewable natural processes'' (Maes and Jacobs, 2017). EBA, or NBS in general, are applied at different scales, in different sectors and its implementation integrates various stakeholders, from all levels of governance, local communities and academic fields (Brink et al., 2016). EBA focus primarily on climate change adaptation, so is more limited in scope than NBS as the latter also address other sustainable development challenges. EBA span many systems, processes, and values within the nature-society domain. The main components of EBA include: (1) ecological structures (e.g., watersheds, forests, gardens and green roofs); (2) ecological functions and processes (e.g., how wetlands provide flood protection); (3) adaption benefits (e.g., flood protection and reduced climate-related mortality and morbidity); (4) valuation (e.g., avoided costs or improved quality of life); and (5) ecosystem management practices (e.g., community–based monitoring of a forest or a new green space law) (Brink et al., 2016).

Overall, EBA are a cost-effective way for urban coastal cities to adapt to climate change. Moreover, EBA often provide other environmental benefits, such as mitigating greenhouse gases, improving biodiversity, water and air quality and improving coastal resilience (McVittie et al., 2018). EBA are often used for their socio-economic benefits as well (Geneletti and Zardo, 2016). EBA, compared to other adaptation strategies, are considered as a win-win approach to climate change, as they help avoid maladaptation, and deliver multiple co-benefits (Munang et al., 2013). Examples of co-benefits include clean water and food provision, risk reduction for extreme weather events, carbon storage, and livelihood diversification. EBA provide lasting solutions that are a win for both climate change adaptation and mitigation, as well as for sustainable socio-economic development, environmental protection, and biodiversity conservation (Munang et al., 2013).

Examples of EBA are available in Europe and these can be found from CORDIS, OPPLA case study finder, OPPLA nature-based solutions, LIFE, WeAdapt, and ADAM digital compendium (McVittie et al., 2018). Specific examples are river/lake restoration, nature restoration, water retention, water management, green roofs, coastal protection, coastal erosion, wetland restoration, management, and agroforestry (McVittie et al., 2018). Many of these case studies are implemented on the building, city, or ecosystem levels. In Europe, to respond to flood events, the Town of Pickering in Yorkshire, United Kingdom, has implemented multiple EBA measures, such as flood basins, ponds, and forest riparian buffers; the Comana wetlands in Romania were reconstructed to conserve biodiversity, natural habitats, and flora and fauna; while in Portugal, a water retention landscape has been developed which includes lake restoration, and land use conservation, among others (McVittie et al., 2018).

According to McVittie et al. (2018), the key factor to successfully implement EBA is the involvement of stakeholders throughout the implementation process. This includes their engagement in the implementation process and knowledge sharing between and amongst groups. Next to stakeholder involvement, is the demonstration of private benefits, the demonstration of co-benefits, and the use of trusted intermediaries. A challenge that hinders successful EBA implementation is the limited knowledge about the biophysical and economic benefits, or the potential negative impacts of EBA (e.g., afforestation with non-native species or green gentrification), therefore making research and EBA monitoring crucial (Lehmann et al., 2021; McVittie et al., 2018). Nalau et al. (2018) examined the main EBA constraints and these fall under the categories of economic and financial; governance and institutional; physical and

biological; social and cultural; and knowledge constraints and gaps. Specific examples include lack of access to financial capital; lack of coordination among actors and governance levels; lack of participatory processes; and imbalance of knowledge sources underpinning assessment. Researchers also found that there is not a clear and consensual definition of EBA, leading to different, and sometimes inadequate, methodologies for the assessment of costs and benefits of EBA interventions (various authors in Nalau et al., 2018). See **Table 2** for a summary of definitions, components, as well as key benefits, success factors and constraints associated with EBA.

Table 2: Summary of the definition, components, key benefits, key success factors and key constraints categories for EBA

Definitions	○ An integrative approach combining biodiversity and ecosystem services within climate change adaptation planning to promote urban capacities to adapt to climate change (adapted from the Secretariat of the Convention on Biological Diversity, 2009). ○ EBA refer to practices that promote socio-ecological resilience by fostering ecosystem services, through ecosystem management that enable people to adapt to the impacts of climate change and reduce their vulnerability (Ojea, 2015).
Components	○ Ecological structures (e.g., watersheds, forests, gardens, and green roofs) (Brink et al., 2016). ○ Ecological functions and processes (e.g., how wetlands provide flood protection) (Brink et al., 2016). ○ Adaption benefits (e.g., flood protection and reduced climate-related mortality and morbidity) (Brink et al., 2016). ○ Valuation (e.g., avoided costs or improved quality of life) (Brink et al., 2016). ○ Ecosystem management practices (e.g., community–based monitoring of a forest or a new green space law) (Brink et al., 2016).
Key Benefits	○ Direct benefits: Improving coastal resilience, adaptation to climate change, mitigating greenhouse gases, and improving biodiversity, water, and air quality (McVittie et al., 2018; Munang et al., 2013). ○ Co-benefits: Enhances critical ecosystem services (e.g. food provision and clean water), secures water resources to cope with drought and flooding; enables viable habitats for people and biodiversity; carbon storage; livelihood diversification; and buffers human communities from natural hazards(e.g., water scarcity or drought, sea-level rise, storm surge, precipitation, temperature change and wind variation leading to erosion (McVittie et al., 2018; Munang et al., 2013).
Key success factors	○ Involvement of stakeholders; demonstration of private benefits and co-benefits; use of trusted intermediaries (McVittie et al., 2018).
Key constraint categories	○ Economic and financial (e.g., access to finance); governance and institutional (e.g., lack of coordination among actors and governance levels); social and cultural (e.g., risk perceptions); physical and biological (e.g., landscape features); and knowledge constraints and gaps (e.g., inadequate research methodologies) (Nalau et al., 2018).

Source: Own elaboration.

1.4. Outlining socio-economic and environmental valuation and assessment approaches

The following pages present the concept of total economic value (TEV) (section 1.4.1), and a synthesis of standard environmental valuation methods (section 1.4.2) based on Ozdemiroglu et al. (2006), Brouwer et al. (2010), Brander et al. (2012), Tietenberg and Lewis (2018) and Selivanov and Hlaváčková (2021). Moreover, section 1.4.3 presents a conceptualization of ecosystem services and further overview of some multi-ecosystem services evaluation tools.

1.4.1. The concept of total economic value (TEV)

The economic concept of value has been broadly defined as any net change in the welfare of society. This concept does not restrict environmental values to benefits from the direct use of a resource. For example, the benefits received from the existence of environmental resources (such as clean water or clean air) add to an individual's well-being, as do the benefits obtained from the consumption of environmental goods (such as steel, timber, or fish). The benefits that individuals obtain in satisfying altruistic desires that arise from their own moral beliefs also have economic value. In this sense, anything from which an individual gains satisfaction is deemed to be of value, if the individual is willing to give up something for it.

Hence, the concept of TEV reflects a) the value from the physical use of environmental resources (both through markets or informally) and b) the value they may attribute to it regardless their current or future use. In other words, TEV corresponds to the sum of use and non-use values.

Use value involves some interaction with the environmental resource under consideration, either directly or indirectly, and hence includes:

- Direct use value: Individuals make use of a resource in either a consumptive way (e.g., the fishing industry and agriculture) or a non-consumptive way (e.g., bird watching).

- Indirect use value: Individuals benefit from ecosystem services supported by a resource rather than using it (e.g., watershed protection for flood mitigation, cycling processes for agriculture or carbon sequestration).

Non-use value is associated with benefits derived from the knowledge that the natural environment is maintained. By definition, non-use value is not associated with any use of the resource or tangible benefit derived from it, although users of a resource might also attribute non-use value to it. Non-use value can be split into the following components:

- Existence value: Derived from the satisfaction of knowing that environmental resources continue to exist, regardless of use made by oneself or others now or in the future (also associated with 'intrinsic value'). The concept may also include the benefits obtained from knowing that culturally important resources are protected.

- Vicarious value: The welfare obtained from the indirect consumption of an environmental resource through books and other media.

- Altruistic value: Derived from knowing that other people can enjoy the goods and services the environment provides.

- **Bequest value:** Associated with the knowledge that the environmental resources will be passed on to future generations.

- **Option value:** An individual derives benefit from keeping open the option to make use of some aspect of an environmental resource in the future, even though he or she does not currently plan to make such use. It can be regarded as a form of insurance to provide for possible future use.

- **Quasi-option value:** A related value arising through avoiding or delaying irreversible decisions, where technological and knowledge improvements can enhance the value of an environmental resource. It is particularly relevant to the precautionary principle. A common example is the potential for genetic information in biodiversity to be used for creating pharmaceuticals or improved crop varieties.

Each of these non-use values can increase welfare and so each must be recognised in any analysis, so that all the benefits from environmental changes may be incorporated. An example of TEV for a forested watershed is illustrated in **Table 3**.

Table 3: Total Economic Value of a Forested Watershed

Direct use value	Indirect use value	Non-use value
- Timber production. - Non-extractive recreation (hiking, bird watching). - Extractive recreation (hunting). - Indigenous/cultural uses.	- Recharge of underground aquifers. - Erosion & flood control through absorption of rain. - Water purification. - Climate control.	- Knowledge of the existence of forested watersheds for other people and/or future generations (existence and/or bequest, vicarious). - Critical habitat for threatened/endangered species (bequest, altruism, option / quasi - option).

Source: Own elaboration.

1.4.2. Economic valuation methods

Some use values can be expressed in monetary terms using data from actual markets. Use values derived from environmental goods and services that are not traded in markets, i.e., are non-market, and non-use values in general, are not reflected in market transactions unless there has been a government intervention in the form of taxation or another policy that forces the market price to incorporate these values.

To overcome the problem of estimating non-market economic values, a range of economic valuation methods has been developed. The appropriateness of differing approaches is varied, with some providing estimates of economic value that are more accepted than others. For instance, using market prices to assess benefits from increased fish stocks may be relatively straightforward. But, this will also provide an under-estimate of the economic value of this gain, since no account is made for any excess willingness to pay over market price, for the fish themselves, for non-use value reasons or other recreational benefits, such as angling.

There are three main approaches of economic valuation methods depending on the type of preference data used: market price proxies (including the production function approach); revealed preference methods (hedonic property pricing, travel cost method and random utility models); and stated preference methods (contingent valuation and choice modelling).

a) Market price proxies

Market price approaches consider the costs that arise in relation to the provision of environmental goods and services which may be observed directly from actual markets. These costs can take the form of opportunity costs or the cost of alternative provision as well as mitigation costs or the costs of aversive behaviour and shadow project costs.

Market price approaches can be proxies for direct and indirect use value but not for non-use values. This is because the price a consumer pays for a good or service is a minimum expression of their willingness to pay for it – they may in fact be willing to pay much more than the market price, i.e., consumer surplus is not accounted for.

Market pricing approaches can only be used for environmental goods and services that are marketed, have clear market-based substitutes, or the degradation of which can be mitigated against. For example, this may include the market value of forest products or spending on improving water quality, storm or flood protection and so on. The opportunity cost approach is suited to assessing the creation or protection of environmental resources such as forests, which typically entails the loss of land for some other productive use (typically agriculture). An example of the cost of an alternative approach is estimating the economic value of coastal wetlands, in terms of storm protection value, on the basis of the cost of constructing equally effective man-made defences. Use of market price data is typically related to appraisal, for example in assessing minimum compensation requirements or estimating mitigation costs.

It should always be borne in mind that market prices can be distorted through monopoly, oligopoly or oligopsony power, government intervention, taxes, subsidies, and so on. Note also that mitigation costs will typically only provide a partial assessment of the environmental impact of interest. For instance, the treatment cost to improve water quality will only account for the impact experienced by water companies and their customers and will not account for water pollution damages to aquatic ecosystems and other users.

Another example of a market price approach is the **production function**, which focuses on the (indirect) relationship that may exist between a particular ecosystem service and the production of a marketed good. Here, environmental goods and services are considered as inputs to the production process and their value is inferred by considering the changes in production process of market goods that result from an environmental change.

The approach is capable of capturing the indirect use component of TEV. The function provides an explicit method for estimating the importance of environmental goods and services in the production of market goods and services, or conversely, the negative impact that pollution can have on production processes.

In the main, the production function approach is limited to environmental inputs such as water, soil, raw materials, air quality and the ecosystem services that support these such as cycling and regeneration and production. A common example is in the assessment of air quality effects on agricultural and forestry production. The approach can also be used to assess the effect of water quality on agriculture, forestry, fisheries and to assess soil fertility (or soil erosion) as a factor input to agriculture. The results can be used to demonstrate the importance of environmental inputs, appraisal of pollution control options and setting minimum compensation amounts for liability. The approach can also feed into cost-benefit, cost-effectiveness, and multi-criteria analyses.

b) Revealed preference methods

Hedonic property pricing is based on the notion that the price at which a property sells is determined, in part, by the environmental characteristics of the surrounding location. The economic value of the environmental characteristics is estimated by regressing the sale price against all factors thought to affect the price.

The method can estimate the environmental costs and benefits that property buyers and sellers are aware of and hence can reflect in their selling and buying behaviour. Within this scope, the value components that can be measured are limited to direct and indirect use values.

The method is generally used for localised and site-specific impacts, including both 'goods' such as pleasant views (and related increases in property price) and 'bads' such as traffic noise, disamenity due to proximity of landfills, and so on (and related decreases in property price). The scope of studies applying hedonic pricing methods is limited to environmental characteristics which are observable by individuals and are likely to have an impact over the period of occupancy. This, by definition, excludes changes that are yet to occur. The method is less applicable to environmental goods/bads which are not typically perceived by the buyer, such as chemical hazard, radiation, etc. The method can be used to input into cost-benefit analysis (projects and policies), 'demonstration' of importance of an issue, establishing the basis for a tax and legal damage assessment. An example of actual practical use was in the revision of the UK Landfill Tax.

The travel cost method is a survey-based technique that uses the cost incurred by individuals travelling to and gaining access to a recreation site as a proxy for the recreational value of that site. Costs considered are travel expenditures, entrance fees, and the value of time.

The method differs from market pricing approaches in that it constructs demand curves for the site to estimate consumer surplus. However, it is still limited to measuring direct (non- consumptive) use value alone. Note that users, in this case, visitors to a site, could also hold non-use values but these cannot be estimated separately.

The method is typically limited to valuing environmental goods and services that have explicit recreational uses, such as woodlands, wetlands, rivers and lakes, national parks and coastal areas. It is not able to account for environmental goods (or bads) that are imperceptible to visitors. Since the method is generally used to estimate recreational benefits, it can be used for entry pricing for any environmental site open to recreation and demonstration of the importance of a site.

The Random utility model is an extension of the travel cost method but is used for testing the effect of changing the quality or quantity of an environmental characteristic at a particular site. Instead of estimating the overall demand for recreational trips, this method focuses on the choice an individual visitor makes when deciding which site to visit.

The component of TEV estimated is direct use value. Note that users - in this case, visitors to a site - could also hold non-use values but these cannot be estimated separately.

As with the travel cost method, this method is suited to estimating the value of environmental goods and services associated with open-access recreation resources such as national parks, woodland, forest, rivers, lakes, wetlands and coastal areas. The random utility model can be applied to estimate the change in recreational use value which arises from a change in the characteristics of a recreational site. It can, therefore, be used for appraisal and site management planning, such as inputting to cost-benefit analysis of projects which may affect specific aspects of recreational sites.

c) Stated preference methods

The **contingent valuation method (CVM)** is a survey-based approach to valuing environmental goods and services. The approach entails the construction of a hypothetical, or 'simulated', market via a questionnaire where respondents answer questions concerning what they are willing to pay (or willing to accept) for a specified environmental change. The approach defines the environmental goods and services as a bundle of different characteristics (quality, quantity, different services etc.) and seeks to elicit willingness to pay for the entirety of the bundle.

The method is able to estimate the TEV of an environmental good or service, i.e., both use value and non-use value components (and values held by both users and non-users). However, separate valuation of all relevant ecosystem services within a single study is likely to be too onerous (and arguably not necessary), as is the separation of total economic value to its constituent parts. Stated preference techniques such as the CVM and choice modelling (see below) are the only approaches to estimate non-use value associated with environmental goods and services.

Choice modelling is based around the notion that goods and services can be described in terms of characteristics (or 'attributes') and the levels that these characteristics take. For example, a lake may be described in terms of its ecological quality, chemical water quality, number, and type of species it provides habitat for, and so on. A choice modelling questionnaire presents respondents with different combinations of these attributes and asks them to choose their most preferred combination or rank their preferences in order. As each combination has a 'price' attached, subsequent analysis of respondents' choices reveals their willingness to pay (WTP) or willingness to accept compensation (WTA) for each of the characteristics (or attributes) presented to them.

As with contingent valuation, choice modelling is able to estimate the total economic value of an environmental good or service, i.e., both use value and non-use value components (and values held by both users and non-users). As goods and services are defined in terms of their attributes and as these are changed, choice modelling is more flexible in estimating individual values for different ecosystem services (subject to these being perceived by individuals). However, the separation of total economic value into its constituent parts is as difficult (and arguably unnecessary) for choice modelling as it is for contingent valuation.

In addition to the previous three main approaches for economic valuation, there are techniques that allow to apply the results of primary valuation studies in other areas.

The **benefit transfer method** allows to apply economic values estimated at one site where the original study took place (the 'study' site) to another site, which has similar characteristics (the 'policy' site). The rational for benefits transfer is that using previous research results in new policy contexts saves effort and expenditure involved in undertaking original research. The result will never be as good as an original valuation study, and the key to its application therefore is to assess acceptable errors. Although benefits transfer is used extensively in practice and is certainly a valuable input to appraisal, its limitations should be recognised. The robustness of benefits transfer depends on the success of the 'matching' of policy site circumstances to an appropriate study site and the quality of the original economic valuation study.

Another example is **meta-analysis**, which develops a statistical aggregation of results of primary studies, and that can also be used for value transfer through a meta-analysis function where results from the assessed studies are applied to a new site.

1.4.3. Ecosystem services conceptualization and evaluation

Human well-being is closely connected to the state and conservation of ecosystems as these directly and indirectly provide a wide range of benefits. These are also understood as ecosystem services, which may include, *inter alia*, the provision of food and other resources, climate regulation, bioremediation of waste, or cultural heritage values.

A key breakthrough initiative for the understanding and analysis of ecosystem services is the Millennium Ecosystem Assessment (MEA, 2003). MEA considers four categories of ecosystem services: i) Provisioning services, which correspond to the resources obtained from nature (e.g., food, timber, medicinal resources); ii) Cultural services, comprising benefits such as aesthetic and spiritual experience or the support of recreation activities by ecosystems; iii) Regulating services, which are associated to the benefits derived from various ecosystem processes (e.g., climate regulation, erosion control); and iv) Supporting services, which are the essential for the provision of all other ecosystem services (e.g. , primary production, nutrient cycling, and provisioning of habitat).

Nevertheless, the topic of 'Ecosystem services' has been under the scientific focus in the past decades, with a subsequent development of different typologies adapted to specific biomes and ecosystems. Another important inventory of ecosystem services is the Common International Classification of Ecosystem Services (CICES)[1], which was developed with the support of the European Environment Agency (EEA). The CICES structure is somewhat different from MEA, presenting a cascade-based classification of ecosystem services, from general to more specific: Section, Division, Group, Class, and Class type (**Figure 1**).

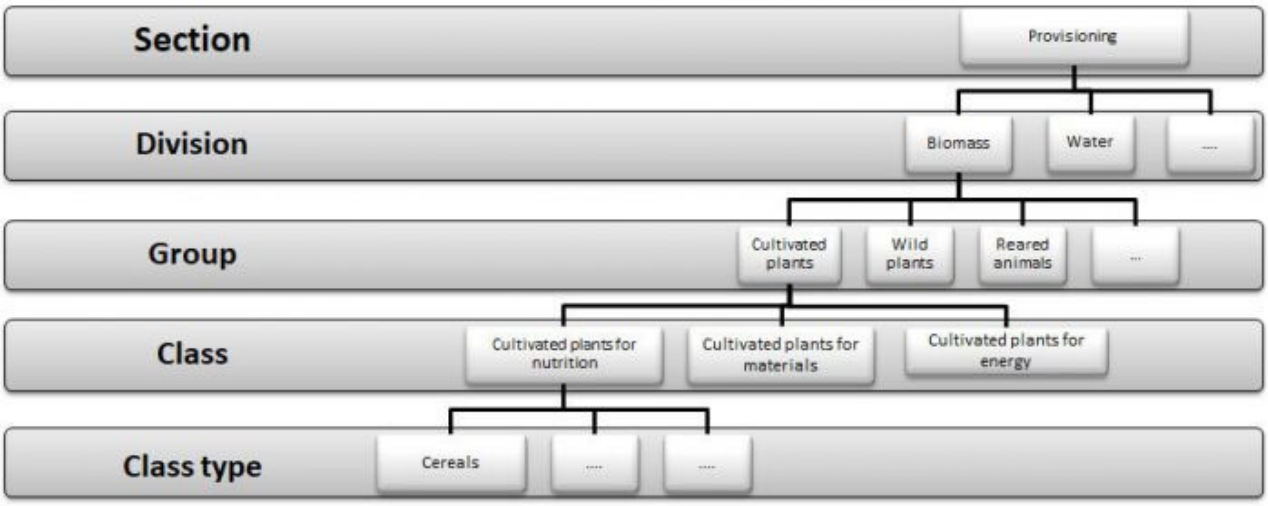

Figure 1: Structure of CICES (v5.1.) Source: https://cices.eu/cices-structure/ (accessed in January 2022).

Table 4 provides more information about the different ecosystem services considered in CICES (v5.1).

[1] https://cices.eu/.

Table 4: Ecosystem services classification according to CICES (v5.1)

Section	Division	Group	Class (examples)[1]
Provisioning (Biotic)	Biomass	Cultivated terrestrial plants for nutrition, materials, or energy	Cultivated terrestrial plants (including fungi, algae) grown for nutritional purposes.
		Reared animals for nutrition, materials, or energy	Animals reared for nutritional purposes.
		Reared aquatic animals for nutrition, materials, or energy	Animals reared by in-situ aquaculture for nutritional purposes.
		Wild plants (terrestrial and aquatic) for nutrition, materials, or energy	Fibres and other materials from wild plants for direct use or processing (excluding genetic materials).
		Wild animals (terrestrial and aquatic) for nutrition, materials, or energy	Wild animals (terrestrial and aquatic) used as a source of energy.
	Genetic material from all biota (including seed, spore or gamete production)	Genetic material from plants, algae, or fungi	Seeds, spores, and other plant materials collected for maintaining or establishing a population
		Genetic material from animals	Wild animals (whole organisms) used to breed new strains or varieties.
		Genetic material from organisms	Individual genes extracted from organisms for the design and construction of new biological entities.
	Other types of provisioning service from biotic sources	Other	Other
Provisioning (Abiotic)	Water	Surface water used for nutrition, materials, or energy	Surface water for drinking.
		Ground water for used for nutrition, materials, or energy	Ground water (and subsurface) used as an energy source
		Other aqueous ecosystem outputs	Other
	Non-aqueous natural abiotic ecosystem outputs	Mineral substances used for nutrition, materials, or energy	Mineral substances used for nutritional purposes
		Non-mineral substances or ecosystem properties used for nutrition, materials, or energy	Wind energy
		Other mineral or non-mineral substances or ecosystem properties used for nutrition, materials, or energy	Other
Regulation & Maintenance (Biotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of wastes or toxic substances of anthropogenic origin by living processes	Bioremediation by micro-organisms, algae, plants, and animals
		Mediation of nuisances of anthropogenic origin	Smell reduction
	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Control of erosion rates
		Lifecycle maintenance, habitat and gene pool protection	Pollination (or 'gamete' dispersal in a marine context)
		Pest and disease control	Pest control (including invasive species)
		Regulation of soil quality	Weathering processes and their effect on soil quality
		Water conditions	Regulation of the chemical condition of freshwaters by living processes
		Atmospheric composition and conditions	Regulation of temperature and humidity, including ventilation and transpiration
	Other types of regulation and maintenance service by living processes	Other	Other
Regulation & Maintenance (Abiotic)	Transformation of biochemical or physical inputs to ecosystems	Mediation of waste, toxics and other nuisances by non-living processes	Dilution by freshwater and marine ecosystems
	Regulation of physical, chemical, biological conditions	Regulation of baseline flows and extreme events	Mass flows
		Maintenance of physical, chemical, abiotic conditions	Maintenance and regulation by inorganic natural chemical and physical processes
	Other type of regulation and maintenance service by abiotic processes	Other	Other

Section	Division	Group	Class (examples)[1]
Cultural (Biotic)	Direct, in-situ and outdoor interactions with living systems that depend on presence in the environmental setting	Physical and experiential interactions with natural environment	Characteristics of living systems that that enable activities promoting health, recuperation or enjoyment through active or immersive interactions
		Intellectual and representative interactions with natural environment	Characteristics of living systems that enable scientific investigation or the creation of traditional ecological knowledge
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Spiritual, symbolic and other interactions with natural environment	Elements of living systems that have symbolic meaning
	Indirect, remote, often indoor interactions with living systems that do not require presence in the environmental setting	Other biotic characteristics that have a non-use value	Characteristics or features of living systems that have an existence value
	Other characteristics of living systems that have cultural significance	Other	Other
Cultural (Abiotic)	Direct, in-situ and outdoor interactions with natural physical systems that depend on presence in the environmental setting	Physical and experiential interactions with natural abiotic components of the environment	Natural, abiotic characteristics of nature that enable active or passive physical and experiential interactions
		Intellectual and representative interactions with abiotic components of the natural environment	Natural, abiotic characteristics of nature that enable intellectual interactions
	Indirect, remote, often indoor interactions with physical systems that do not require presence in the environmental setting	Spiritual, symbolic, and other interactions with the abiotic components of the natural environment	Natural, abiotic characteristics of nature that enable spiritual, symbolic, and other interactions
		Other abiotic characteristics that have a non-use value	Natural, abiotic characteristics or features of nature that have either an existence, option, or bequest value
	Other abiotic characteristics of nature that have cultural significance	Other	Other

Source: Summarised version based on https://cices.eu/cices-structure/ (accessed in January 2022).

Note: [1] A complete overview of all classes is available on the CICES website.

There are several available tools for the assessment of multiple ecosystem services, and consequent support of the decision-making process. A non-exhaustive compilation of useful tools is presented in below (**Table 5**).

Table 5: Selective list of ecosystem services assessment tools

Tool	Description	Target users	Spatial scale of analysis	Time requirement	Capacity for independent use	Examples of main outputs	Examples of case studies
ARIES (Artificial Intelligence for Environment & Sustainability)	This open-source tool aims to map, and quantity ecosystem services flows by integrating its spatial-temporal dynamics and complexity.[1] ARIES combines scientific data and modelling to jointly analyse socio-economic and environmental systems. ARIES can be applied with the following purposes: "spatial mapping and quantification of ecosystem services; spatial economic valuation of ecosystem services; natural capital accounting; optimization of payment schemes for ecosystem services (PES); conservation planning; spatial policy planning; and forecasting of change in ecosystem service provision."[2]	Policy makers, NGOs, consultants, companies, etc.[3]	Local, watershed, regional, national.[2]	Low (for pre-existing case studies) to high (for new case studies).[4]	Yes, through web interface (ARIES Explorer) or software tool.[2, 4]	- Ecosystem service flow trajectories simulated are processed into different types of maps.[1] - Quantitative data on ecosystem services (biophysical values, potentially monetized).[4, 5] - Environmental asset portfolio.[5]	"Analysis of transboundary water ecosystems and green/blue infrastructures in the Intercontinental Biosphere Reserve of the Mediterranean Andalusia (Spain) – Morocco." (H2020 Project AQUACROSS; Grant Agreement no. 642317).[2] ARIES was applied in the spatial mapping of provisioning services (water supply); maintenance and regulation services (flood regulation; carbon sequestration; pollination; soil retention); and cultural services (recreational opportunities).[6]
TESSA (Toolkit for Ecosystem Service Site-Based Assessment)	Toolkit based on an interactive workbook that guides the measurement and monitoring of ecosystem services at the site level, allowing for the comparison of two alternative scenarios (e.g., before and after a restoration project).[5, 7] The methodological framework proposed by TESSA favours stakeholder engagement in different stages such as ecosystem service identification, methods selection, data acquisition and analysis, and communication.[8]	A wide range of different stakeholders (e.g., NGOs; community-based organizations; site-managers; academics; farmers; etc.).[8, 9]	Landscape/site-specific.[8]	Low.[8]	Yes, using the open access toolkit.[5, 8]	- Quantitative data on ecosystem services (biophysical and monetary data). [5, 8] - Comparison between alternative states of a particular site (e.g., through a cost-benefit analysis; or the analysis of the overall balance of ecosystem services provision).[8]	Ecosystem service assessment focused on the potential benefits of coastal managed realignment projects in two UK regions (Hesketh Outmarsh West, northwest England; and the Inner Firth of Forth, central Scotland). The assessed ecosystem services included agricultural production, wildfowling and fish production, global climate regulation, flood and storm surge protection, and recreation.[9]
InVEST (Integrated Valuation of Ecosystem Services and Tradeoffs)	Collection of open-source software models for mapping and valuation of ecosystem services. It allows to assess how changes in ecosystems affect the flow of services and benefits to humans.[8, 10]	Governments, NGOs, corporations, farmers, landowners, etc.[5, 10]	Site scale, local, landscape, regional, national, global.[5, 10]	Low to high, depending on data availability.[4, 8]	Yes, with the need of basic – intermediate GIS skills.[4, 5]	Results are presented in biophysical (e.g., tons of carbon sequestered) or economic units (e.g., net present value of).[10] This tool also allows to generate maps.[5]	The evaluation of the impacts of land-use changes on ecosystem services in an ecological conservation area located in the western part of Beijing (China). This study focused on carbon storage and sequestration, flood regulation, soil conservation,

Tool	Description	Target users	Spatial scale of analysis	Time requirement	Capacity for independent use	Examples of main outputs	Examples of case studies
							water purification, habitat quality, and crop production.[11]
MIMES (Multiscale Integrated Models of Ecosystem Services)	Open-source models available for mapping and assessing the impact of different management options on ecosystem services and their linkages to human well-being. MIMES' interaction matrix between natural and human systems includes the dimensions of natural, human, built, and social capital.[4, 5, 8]	Scientists, policy makers, natural resource managers, etc.[5]	Landscape to global.[8]	Low to potentially high, the latter if it applies to new case studies.[4, 8]	Yes, but depending on the access to modelling software.[4]	Multiple outputs such as the contribution of ecosystem services to economic production, the perceived scarcity of ecosystem services for economic sectors, ecological integrity (associated with the ability of a natural system to produce services), etc.[12]	A case study applied in the coastal and marine area of Gloucester (Massachusetts, USA), with a focus on the spatial analysis of trade-offs of ecosystem services that support various sectors (commercial fishing, offshore wind production, and tourism).[12, 13]
Co$ting Nature	Online-based policy-support tool for mapping ecosystem services and natural capital accounting, with a conservation-oriented purpose. This tool focuses on the opportunity costs of protecting nature and its potential to generate ecosystem services.[4, 5]	NGOs, governmental entities, universities, etc.[14]	Local, landscape, regional, national, multi-scale.[5]	Low.[4]	Yes.[4]	- Maps, GIS databases, ecosystem service impact score.[5] - Economic valuation of ecosystem services.[14, 15]	Analysis of combined spatial distribution and use intensity of a bundle of six potential and realised ecosystem services (water provisioning and supply, water quality, carbon sequestration, carbon storage, flood regulation, and nature-based tourism) in Southern Ontario (Canada).[15]

Sources: [1] Villa et al. (2014); [2] https://aries.integratedmodelling.org/ (accessed in January, 2022); [3] Waage and Stewart (2008); [4] Bagstad et al. (2013); [5] https://ecosystemsknowledge.net/aries (accessed in January 2022); [6] https://aquacross.eu/sites/default/files/D9.2_CS2_28092018_FINAL.pdf; [7] http://tessa.tools/ (accessed in January 2022); [8] Peh et al. (2013); [9] MacDonald et al. (2020); [10] https://naturalcapitalproject.stanford.edu/software/invest, (accessed in January 2022); [11] Li et al. (2020); [12] Boumans et al. (2015); [13] Altman et al. (2014); [14] http://www.policysupport.org/costingnature (accessed in January 2022); [15] Aziz and Van Cappellen (2019).

SYSTEMATIC LITERATURE REVIEW OF SOCIO-ECONOMIC ASSESSMENT STUDIES APPLIED TO CLIMATE CHANGE ADAPTATION

This Systematic Literature Review targeted studies performing socio-economic assessments of climate change adaptation in coastal areas and had the purpose of answering the following general and specific research questions:

1. What socio-economic assessment methods have been used to analyse adaptation strategies?
   1.1. Do these methods fall under Multicriteria analysis (MCA), Cost-benefit analysis (CBA), Cost-effectiveness analysis (CEA) or other types of assessments?
   1.2. To which extent are these methods expert-based or participatory?
2. In which adaptation context have these assessment methods been utilized?
   2.1. Which type of adaptation strategies have been utilized in the assessment?
   2.2. What climate change hazards do these adaptation strategies address?
   2.3. What climate change sectoral impacts do these adaptation strategies address?
3. Which monetary and non-monetary metrics have been used to assess these adaptation strategies?
4. How do these adaptation strategies perform?
   4.1. What were the results of the monetary and non-monetary metrics used?
   4.2. What final recommendations were provided?

This chapter is structured in three main sections and subsections. Section 2.1 describes the methodology. Section 2.2 presents the main results of the review, including information about the number of studies screened, excluded, and finally considered for the review (Sub-section 2.2.1), as well as the presentation of the main characteristics of the assessed studies and the discussion of the research questions (Sub-section 2.2.2). Section 2.3. discusses the main results.

1.5. Methodology

This systematic review is based on the Preferred Reporting Items for Systematic Reviews and Meta-Analysis (PRISMA 2020) methodology[2]. The use of PRISMA ensures consistency and allows "to improve the quality of systematic review protocols, helping authors to document a roadmap prior to completing it" (Bueno et al., 2021).

[2] http://www.prisma-statement.org/.

This methodology establishes a framework for the systematic literature review structured in four main stages:

Stage 1. Identification of studies: search string combinations are introduced in different databases to identify the target studies.

Stage 2. Eligibility: language and timeline filters are activated and followed by the search string combinations to obtain the first list of studies.

Stage 3. Screening: title, abstract and full text of the identified references is analysed to check its compliance with the inclusion criteria defined.

Stage 4. Inclusion for the analysis: once the inclusion criteria is satisfied and duplicates are removed, the selected references are analysed based on a list of variables, allowing to answer to the research questions stated.

The following subsections will provide more detail about how the previous stages were implemented in the systematic review presented in this report.

2.1.1. Stage 1: Identification of studies

The literature search was applied to the following databases during the months of November and December of 2021: Web of Science (WoS)[3]; Scopus[4]; Zenodo[5]; the European Climate Adaptation Platform Climate-ADAPT[6]; and the Community Research and Development Information Service (CORDIS)[7]. WoS and Scopus were selected because of their large databases of scientific peer-reviewed literature; Zenodo as an open repository of scientific and non-scientific literature; CORDIS as an important database for EU funded project publications; and Climate-ADAPT due to its relevance as a database of quality checked information about climate change.

The search string presented in **Table 6** was selected to capture studies that performed socio-economic assessments of adaptation measures or strategies to climate change in coastal, and mainly urban areas. This search was operated through 27 different combinations of keywords.

Table 6: Search string

Field of analysis		Form of analysis		Environmental issue		Environmental action		Geographical context
socio-economic*	AND	assessment	AND	climate change	AND	adaptation	AND	coastal
socioeconomic*		analysis						urban
economic		evaluation						city

Source: Own elaboration.

Note: * "socio-economic" and "socioeconomic" are included in the search string due to the wide use of both versions of this term (with and without the hyphen) in the literature.

[3] http://www.webofscience.com.
[4] https://www.scopus.com/home.uri.
[5] https://zenodo.org/.
[6] https://climate-adapt.eea.europa.eu/.
[7] https://cordis.europa.eu/es.

2.1.2. Stage 2: Eligibility

The identification of studies (Stage 1) was implemented alongside with a first set of eligibility criteria. The searches were limited to entries that contained the search string words within their title and abstract, as well as to English written and published studies between 2010 and 2021. Afterward, duplicated, unreadable and unpublished references were excluded. Moreover, other eligibility and exclusion criteria were defined for the following stage (Screening). **Table 7** presents the full list of criteria.

Table 7: Eligibility and exclusion criteria

Criterion	Eligibility criteria	Exclusion criteria
Timeline or period	2010-2021	Pre-2010
Language	English	Non-English
Type of publication	Empirical studies, conceptual and grey literature	News, non-empirical studies
Publication status	Published	Non-published
Geographical context	Coastal areas	Others
Spatial scale	Local, regional	National, continental, global
Type of assessment	Socio-economic	Non-socioeconomic
Environmental issue/action	Studies focused on Climate Change related impact and specific adaptation strategies/measures	Not potentially related to Climate Change impact and adaptation

Source: Own elaboration.

2.1.3. Stage 3: Screening

The screening process was divided into two steps (**Figure 2**):

- In the first part of the screening, title and abstract were checked to be consistent with the eligibility criteria presented in Table 7. Records not complying with these criteria were excluded, and those records fulfilling it were included in the second step of the screening process, which involved the analysis of the full text of the selected references.
- During the second part of the screening, several records were considered as not eligible for the following stage - literature review analysis (LRA) - because they either not complied with the eligibility criteria and/or were irrelevant for the research questions stated.

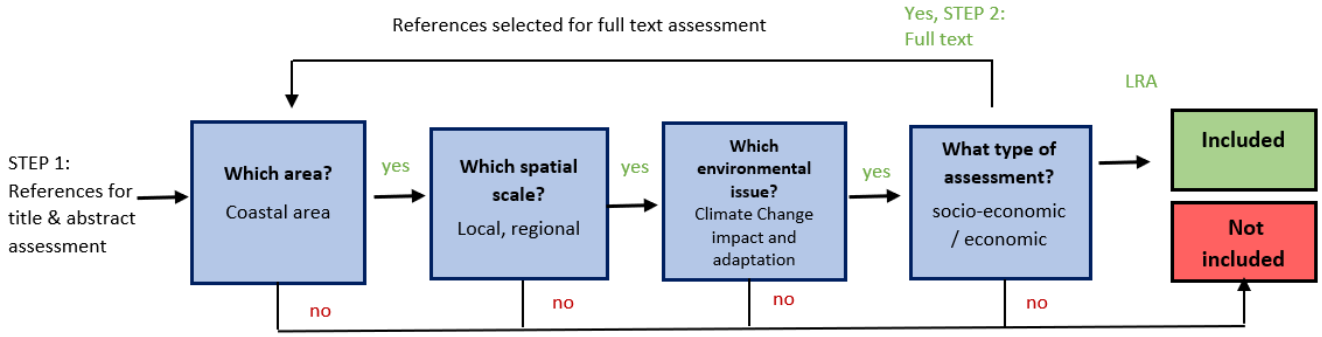

Figure 2: Overview of the screening process

Source: Adapted from Heckwolf et al. (2021).

2.1.4. Stage 4: Inclusion for the analysis

The final step was to integrate the screening results of the different databases used. For the full text assessment, a source code table (**Table 8**) was designed to guide this process. The source code includes a set of variables that gather the general characteristics of the studies in relation to the research questions stated. The selected variables were grouped in the following sections: A. Basic information; B. Socio-economic assessment methods; C. Adaptation context; D. Metrics; and E. Performance. The full text assessment was performed by recording the results on an Excel spreadsheet with further double-checking.

Table 8: Source code table for full text assessment

No.	Coding Fields
A.	**Basic information**
1	Article ID
2	Authors
3	Year of publication
4	Article title
5	Name of journal
6	Keywords used (in the article)
7	Type of publication (A – Article, B – Book, C – Book Chapter, D - Report, E - Others)
8	Geographical Scale (A – Regional/provincial; B – Urban/peri-urban; C – District/neighbourhood/ street)
9	Geographical location(s)
B.	**Socio-economic assessment methods**
1	Assessment method (A – Multiple criteria analysis; B – Cost benefit analysis; C – Cost effectiveness analysis; D – Others; If others, please specify it)
2	Timing of the assessment (A – ex ante; B – interim; C – final or post evaluation)
3	Aim of the assessment method
4	Stakeholders involved (A – Citizens and citizens groups; B – Public authorities; C – Researchers/Academicians; D – Private Sector)
5	Steps in which stakeholders were involved
C.	**Adaptation context**
1	Type of adaptation strategies assessed (A – EBA; B – Hard; C – Soft; D – Hybrid)
2	Specific adaptation strategies assessed
3	Climate hazards addressed by the adaptation strategies (A – Sea level rise; B – Coastal erosion; C – Flooding; D – Multi hazards; E – Others; If Multi hazards/others, please specify it)
4	Sectoral climate impacts addressed by the adaptation strategies (A – Risk to tourism; B – Loss of cultural heritage; C – Damage to commercial buildings; D – Damage to residential buildings; E – Energy networks; F – Agriculture stress; G – Loss of wetlands; H – Loss of animal habitat; I – Damage to civil infrastructure; J – Risk to local economy; H – Others; If others, please specify it)
D.	**Metrics**
1	Monetary

No.	Coding Fields
2	Non-monetary
E.	**Performance**
1	Results of the assessment
2	Final recommendations provided, including policy recommendations

Source: Own elaboration.

1.6. Results

This section presents the main findings of the systematic literature review. First, the PRISMA 2020 flow diagram will show the number of records removed before the screening, excluded, and retrieved during the screening process, and finally, the number of records assessed for eligibility. Second, the main characteristics of the assessed studies will be presented. This represents the analysis of the variables considered in **Table 8** and provides the basis to answer to the research questions.

1.6.1. Literature selection

From a total of **6,501 registers identified in the five databases**, 4,501 records were duplicated and removed before the screening process and 24 records were removed for other reasons (not written in English, or full references not published). As a result, **1,976 records were eligible for title and abstract screening**. After screening the title and the abstract, 1,355 records were excluded due to non-compliance of the eligibility criteria (**Table 7**).

Accordingly, **614 references were found eligible for the full-text screening**. These records were first grouped by assessment typology (MCA, CBA including CEA, Other) and further screened. This process resulted on the exclusion of 563 records due to the following reasons: 104 records did not comply with the eligibility criteria (Reason 1); 357 records were considered irrelevant for the research questions stated (Reason 2); and finally, when integrating the screened records of the assessment typologies considered, 102 duplicates were still identified and excluded (Reason 3). Most of these duplicates arose from WoS and SCOPUS databases.

The full-text screening resulted in **51 valid references for the literature review analysis**. The process ranging from the initial identification to the final selection of studies was implemented in November and December of 2021. **Figure 3** provides an overview of the identification of studies through the PRISMA 2020 flow diagram.

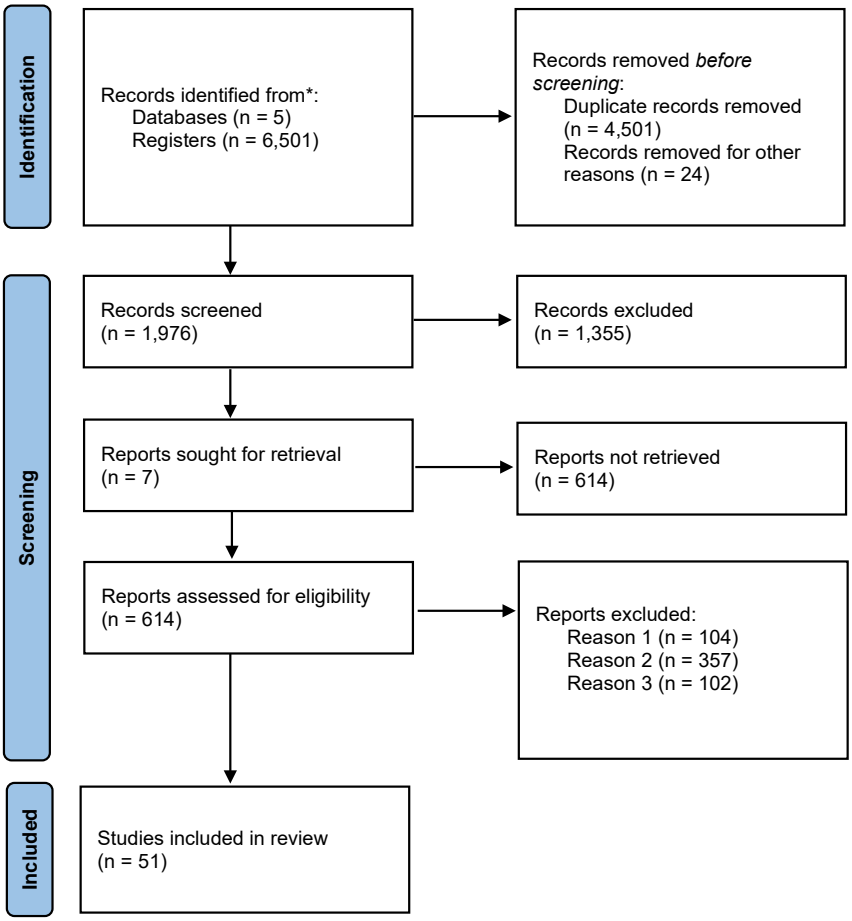

Figure 3: PRISMA 2020 flow diagram for new systematic reviews. Results overview

Source: Own elaboration based on Page et al. (2021).

1.6.2. Literature review analysis

This section summarises the main results of the literature review analysis, presenting the information about the proposed variables characterising the selected studies (See **Table 8**), and allowing to answer the research questions. The following sections are structured as follows: a) Basic information; b) Socio-economic assessment methods used to analyse adaptation strategies; c) Adaptation context; d) Metrics; and c) Performance. A more detailed presentation of the characteristics of the studies is available in **Appendix 1**.

a) Basic information

A total of **51 studies were included in the final stage of the literature review analysis**. Although this review targeted the period 2011–2021, **50% of the selected references were published in 2018** and in the following years (Figure 4). **A significant majority of the analysed records are peer reviewed scientific articles (n=45)**, followed by conference papers (n=3), reports (n=2) and book chapter (n=1).

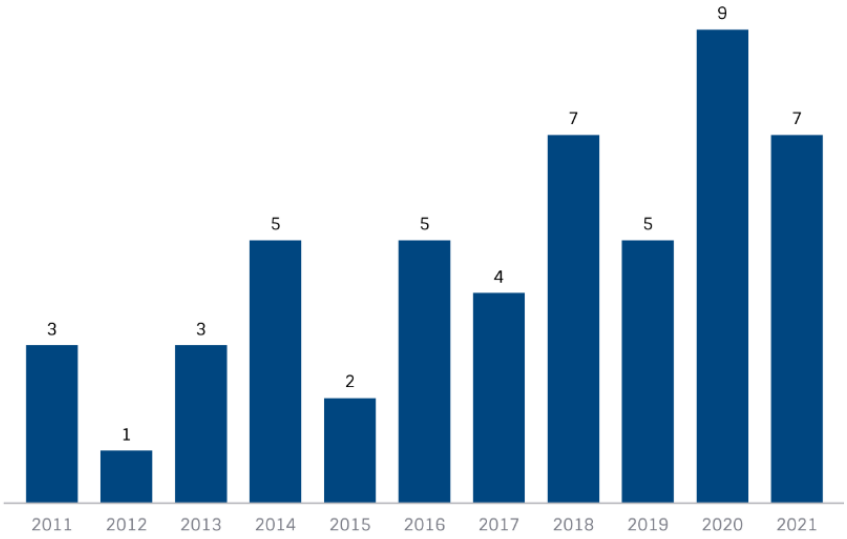

Figure 4: Year of publication of the reviewed studies

Source: Own elaboration.

When looking at the **keywords used in the studies, 'climate change' was the most repeated term, appearing in 20 publications**, followed by 'Cost-benefit analysis' (n=9), and 'sea-level rise' and 'adaptation', both appearing in eight publications. The latter keyword was often used in combination with other terms such as 'measures', 'cost(s)', 'strategies', 'options', 'pathways' or 'policy'. This was also the case of 'coastal', which was combined with 'flood(ing)', 'inundation', 'management', 'risks setback', 'hazards', 'protection', 'erosion', 'structures', and 'tourism'; 'urban', which was associated with 'development modelling', 'drainage' and 'drainage system', 'flood', 'green areas', 'green system', 'regeneration', 'resilience', 'resilient development' and 'threats and vulnerabilities'; and 'flood', which is combined with 'damage', 'defence', 'protect', 'reduction', 'risk', and 'risk assessment'. Climate change adaptation (n=6) and ecosystem services (n=4) also had some significance (Figure 5).

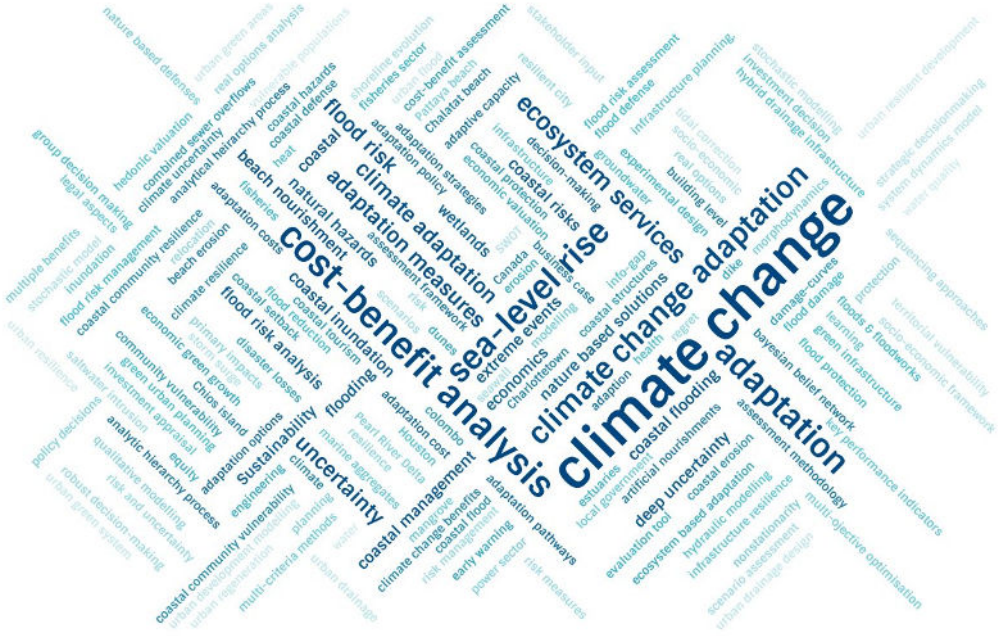

Figure 5: Word cloud of keywords of the reviewed studies

Source: Own elaboration.

The case studies of the selected publications were mainly conducted at the regional/provincial scale (49% of analysed records), followed by urban/peri-urban scale (39%), and district/neighbourhood level (12%). Regarding the geographical location of the case studies, EU countries were documented 41 times, and non-EU countries 33 times. The top three countries documented in the case studies were the USA (9 times), Australia (6), and France (5). At the continental level, Africa and South America were not represented (**Table 9**; **Figure 6**).

Table 9: Countries assessed in the reviewed studies (frequency)

Geographical location	Total
Belgium	2
Bulgaria	1
Croatia	1
Cyprus	1
Denmark	4
Estonia	1
Finland	1
France	5
Germany	2
Greece	3
Ireland	1
Italy	2
Latvia	1
Lithuania	1
Malta	1
Netherlands	3
Poland	1
Portugal	4
Romania	1
Slovenia	1
Spain	4
Sweden	1
Total EU countries	41
Australia	6
Canada	2
China	2
India	1

Geographical location	Total
Mexico	4
Norway	1
Singapore	1
Sri Lanka	1
Thailand	1
UK	2
USA	9
Vietnam	3
Total Non-EU countries	**33**
Not specified	1
Total	**75**

Source: Own elaboration.

Notes: Some articles developed case studies in more than one country, thus explaining why the sum of the frequency (n=75) is higher than the assessed articles (n=51). This was the case of Vousdoukas et al. (2020), which performed an analysis of several European coastal regions, and of WBCSD (2014), which focused on USA and Mexico.

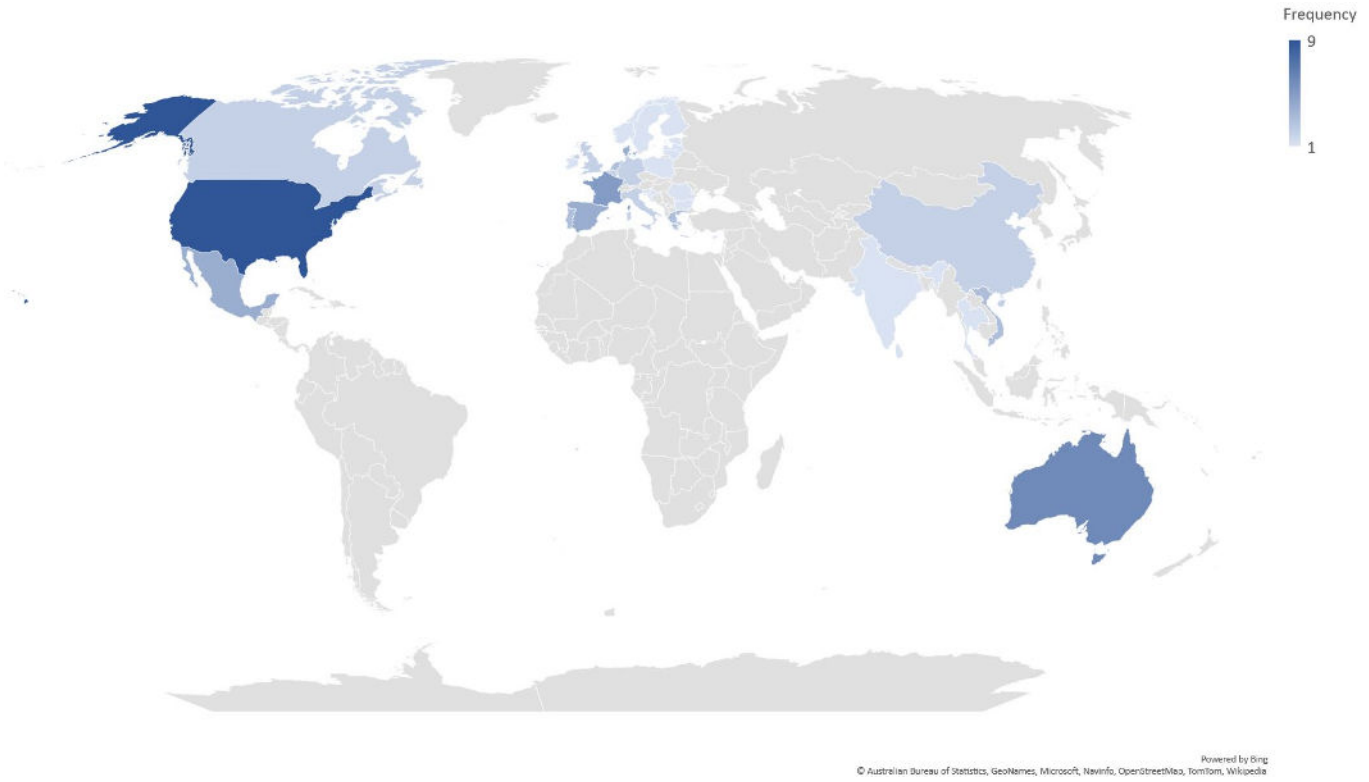

Figure 6: Map representation of the countries included in the reviewed studies (frequency)

Source: Own elaboration.

b) Socio-economic assessment methods used to analyse adaptation strategies

The **socio-economic assessment methods used to analyse adaptation measures/strategies were grouped into five categories: Multicriteria-analysis (MCA); Cost-benefit analysis (CBA); combined MCA/CBA; combined CBA/Cost-effectiveness analysis (CEA); and 'other' types of methods**. MCA was performed in six studies; three studies combined MCA and CBA; 23 studies applied only CBA; two studies combined CEA and CBA; and 17 references performed 'other' types of assessments. A summary of the reviewed authors in each category is described below (**Table 10**).

Table 10: Assessment methods and studies reviewed

Assessment method	Studies		
	Nº	% over the total	References
MCA	6	12%	Mostofi Camare and Lane (2015); Sturiale and Scuderi (2019); Alves et al. (2020); Baills et al. (2020); Andreadis et al. (2021); Nguyen and Bleys (2021).
MCA/CBA	3	6%	Van den Eynde et al. (2011); Harper et al. (2013); Tonmoy et al. (2015).
CBA	23	45%	McNamara et al. (2011); Tsvetanov and Shah (2013); Zhou et al. (2012, 2013); WBCSD (2014); André et al. (2016); Fletcher et al. (2016); Abadie et al. (2017); Haer et al. (2017, 2018); Radhakrishnan et al. (2018); de Ruig et al. (2019, 2020); Wagenaar et al. (2019); Coelho et al. (2020); Du et al. (2020); He et al. (2020); Locatelli et al. (2020); Oanh et al. (2020); Vousdoukas et al. (2020); Ritphring et al. (2021); van der Pol et al. (2021).
CBA/CEA	2	4%	Reguero et al. (2014, 2018).
Other	17	33%	Hallegatte (2011, 2016); Berte and Panagopoulos (2014); Metcalf et al. (2014); Bloetscher et al. (2016); Freire et al. (2016); Kuhfuss et al. (2016); Abadie et al. (2017); Lane et al. (2017); Dawson et al. (2018); Hérivaux et al. (2018); Löwe et al. (2018); Manocha and Babovic (2018); Woodruff et al. (2018); Ćulibrk et al. (2021); Rohat et al. (2021); Schipper et al. (2021).
Total	**51**	**100%**	-

Source: Own elaboration.

The **category 'other'** includes a variety of assessment methods. Some studies evaluated the economic impact of climate change with and without the adoption of adaptation policies. Among these, Löwe et al. (2018) focused on expected annual damages (EAD); Kuhfuss et al. (2016) looked at gains and losses in ecosystem services; and Hallegatte (2011; 2016) focused on total direct and indirect losses through the use of average damage ratios or repair and replacement costs (direct losses) and Adaptive Regional Input-Output (ARIO) models. Moreover, Lane et al. (2017) and Woodruff et al. (2018) both applied system dynamics (SD) modelling, and Ćulibrk et al. (2021) developed a modified version of Demonstrate Ecosystem Services Enabling Innovations in the Water Sector (DESSIN) framework. Examples of other approaches include Rohat et al. (2021) which presented a scenario-based approach for effectiveness assessment of adaptation strategies, or Berte and Panagopoulos (2014), which performed a SWOT analysis of adaptation measures. Other references relied on the application of integrated approaches. Bloetscher et al. (2016) combined a vulnerability assessment with an evaluation of adaptation strategies; Abadie et al. (2017) applied stochastic modelling, risk measures and Real Options Analysis (ROA); Metcalf et al. (2014) combined qualitative modelling and Bayesian Belief Networks (BBN) analysis to produce alternative scenarios and semiqualitative predictions of environmental, social and economic change; Freire et al. (2016) applied a risk

assessment and a decision-making approach; Dawson et al. (2018) performed a ROA to the ex-post economic assessment of the management of coastal rail infrastructure in the United Kingdom (UK); Manocha and Babovic (2018) developed an integrated assessment based on Net Present Value (NPV) and ROA; Hérivaux et al. (2018) presented an assessment of the benefits of adaptation following hazard-modelling and environmental valuation methods; and Schipper et al. (2021) applied a framework combining Sustainability Development Goals (SDG) and Sustainability Impact Score (SIS).

Most of the selected studies (80%) assessed adaptation measures/strategies before being implemented (ex-ante analysis); five studies performed an interim evaluation (Ćulibrk et al., 2021; Schipper et al., 2021; Oanh et al., 2020; Berte and Panagopoulos, 2014; and Metcalf et al., 2014); and only three studies developed a final or post evaluation (van der Pol et al., 2021; Radhakrishnan et al., 2018; and Dawson et al. (2018). Full details about the timing of the socio-economic assessments conducted is provided in **Table 11**.

Table 11: Timing of the socio-economic assessments

Timing	MCA	MCA/CBA	CBA	CEA/CBA	Other	Total
Ex-ante	6	3	19	2	12	42
Interim	-	-	1	-	4	5
Final or post evaluation	-	-	2	-	1	3
Mixed (ex-ante & final)	-	-	1	-	-	1
Total	**6**	**3**	**23**	**2**	**17**	**51**

Source: Own elaboration.

Most of the selected studies (29 out of 51) had as the main aim to evaluate the most effective or preferred adaptation measures/strategies. The remaining studies focused on different objectives, *inter alia*, determining the timing to initiate adaptation strategies, ranking adaptation strategies for decision making, or examining the impact of climate change on ecosystem services.

The extent to which the assessments are expert or participatory-based is somewhat balanced: 21 studies include a participatory-based approach, whereas 30 studies are exclusively expert-based. Nevertheless, when looking at the different assessment methods and the stakeholders involved, several differences arise. MCA and studies combining MCA and CBA methods all rely on a participatory-based approach. Studies combining CBA and CEA are, on the contrary, expert-based analyses. About 25% of the studies performing CBA, and 35% of studies under the category 'other', counted with a stakeholders' involvement process (**Table 12**). Some studies had the involvement of only one type of stakeholder. This was the case of eight studies which had the implication of citizens and citizens' groups, public authorities, and researchers/academicians. Seven studies observed a multi-stakeholder involvement, notably by the previous groups plus representatives from the private sector. The remaining six studies did not specify the types of stakeholders participating.

Table 12: Number of studies with stakeholders' involvement

Stakeholders		MCA	MCA/CBA	CBA	CBA/CEA	Other	Total
Studies with an exclusive involvement of one type of stakeholder	Citizens & citizens' groups	-	-	1	-	2	3
	Public authorities	-	-	2	-	-	2
	Researchers/Academicians	1	-	1	-	1	3
	Private sector	-	-	-	-	-	0
Multi-stakeholders*		4	2	-	-	1	7
Not specified		1	1	2	-	2	6
Total		**6**	**3**	**6**	**0**	**35**	**21**

Source: Own elaboration.

Note: * It includes the participation of citizens and citizens' groups, public authorities, researchers/academicians, and private sector.

Stakeholders (citizens and citizens groups, public authorities, researchers and academicians, private sector) were involved in different stages of the assessments. For example, in Schipper et al. (2021), Metcalf et al. (2014) and Sturiale and Scuderi (2019), stakeholders participated in the definition of the problem and in the identification of alternative adaptation strategies. Other studies counted with the participation of stakeholders in the identification and selection of the most preferred adaptation strategies (e.g., Bloetscher et al., 2016; Radhakrishnan et al., 2018; Locatelli et al., 2020; and Nguyen and Bleys, 2021); in the development and evaluation of the decision criteria for the selection of adaptation options (e.g., Tonmoy et al. 2015; Alves et al., 2020; Baills et al., 2020); or in the estimation of the economic impact related to the selected adaptation strategies (Kuhfuss et al., 2016; Tonmoy et al. 2015; and McNamara et al., 2011).

c) Adaptation context in which these assessment methods have been utilized

Most of the studies focused on the analysis of 'hybrid' adaptation strategies (33 out of 51 studies), followed by studies only addressing hard-based approaches (n=12), EBA (n=4), or soft strategies (n=2). See **Table 13** for full detail of type of adaptation used within each assessment method.

Table 13: Type of adaptation strategies assessed (No. of studies)

Adaptation strategies	MCA	MCA/CBA	CBA	CBA/CEA	other	Total
EBA	2	-	-	-	2	4
Hard	-	-	8	-	4	12
Soft	-	-	-	-	2	2
Hybrid	4	3	15	2	9	33
Total	**6**	**3**	**23**	**2**	**17**	**51**

Source: Own elaboration.

Some examples of specific adaptation measures associated with the categories of 'EBA', 'hard', and 'soft' are indicated in **Table 14**. EBA included measures such as the restoration of specific ecosystems (e.g., wetlands, barrier

reefs); hard-based adaptation relied significantly on interventions aimed at protecting coastal areas from flooding and SLR (e.g., dykes, groynes, seawalls); soft adaptation involved, *inter alia*, restricting and prohibiting construction in coastal and flood-prone areas, or the development of early warning systems.

Table 14: Examples of adaptation measures assessed

Adaptation strategies	Examples of specific adaptation measures
EBA	- Wetland's restorations. - Rehabilitating coastal dunes. - Restoration of barrier/oyster reefs. - Rehabilitation of mangrove forests. - Green roofs. - Urban parks. - Green equipment. - Etc.
Hard	- Dikes, groynes, and seawalls. - Breakwaters. - Stormwater pumping stations. - Storm surge dams. - Drainage systems. - Etc.
Soft	- Plans to restriction permission of coastal constructions. - Ban on the construction of basements in flood-prone areas. - Increase access to health care. - Floodplain zoning. - Early warning systems. - Land elevation. - Sand nourishment. - Etc.

Source: Own elaboration.

Regarding climate hazards, 30 studies focused exclusively on one type of hazard, and from these, flooding appeared in 18 studies. The remaining references (n=21) assessed 'multi-hazards' (**Table 15**).

Table 15: Climate hazards addressed in the selected studies (n)

Climate hazard	MCA	MCA/CBA	CBA	CBA/CEA	Other	Total
A. Sea-level rise (SLR)	-	-	2	-	2	4
B. Coastal erosion	1	-	2	-	-	3
C. Flooding	1	-	12	1	4	18
D. Multi-hazards	2	3	7	1	8	21
E. Other	2	-	-	-	3	5
Total	**6**	**3**	**23**	**2**	**17**	**51**

Source: Own elaboration.

Looking at all climate hazards considered, including those integrated in the 'multi-hazards' category, **'Flooding' was the most repeated hazard (n=33)**, followed by SLR (n=18), storms (n=13), coastal erosion (n=11), temperature-

related hazards (n=8), extreme precipitation (n=6), and other types of hazards (n=5) (**Figure 7**). In fact, the literature review revealed that 'flooding' was the climate hazard addressed by all types of adaptation strategy considered (hard, soft, EBA). This included hard adaptation measures such as dikes, seawalls, levees, flood walls, breakwaters, or drainage systems; soft measures like road, building and land elevation; and EBA dealing with the restoration of mangroves, wetlands, and barrier and oyster reefs.

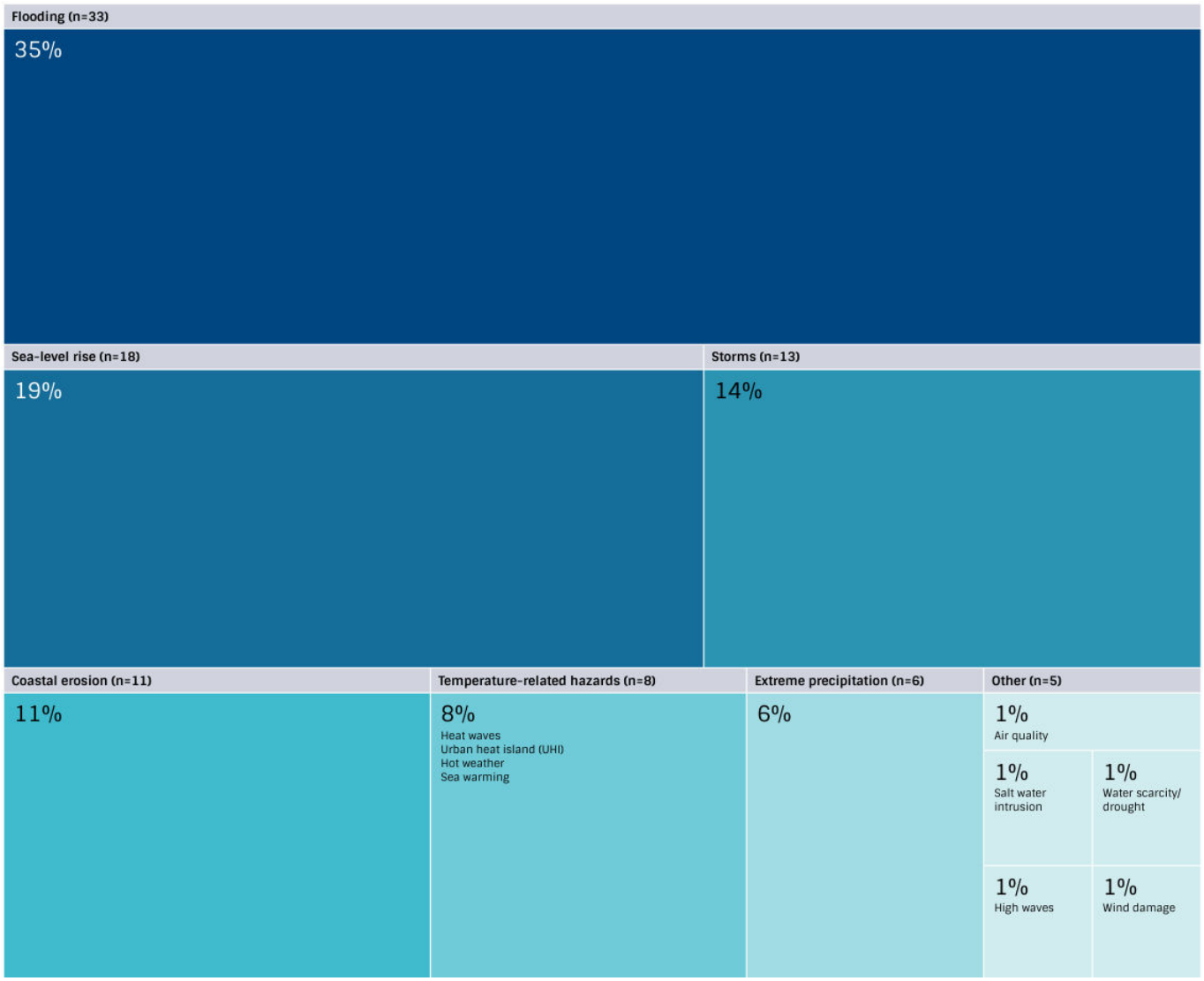

Figure 7: Climate change impacts addressed in the studies (n; %)

Source: Own elaboration.

The three most repeated **climate change sectoral impacts** addressed in the selected studies were 'damage to residential buildings' (n=22), followed by 'damage to commercial buildings' (n=19), and 'damage to civil infrastructure' (n=18) (**Figure 8**).

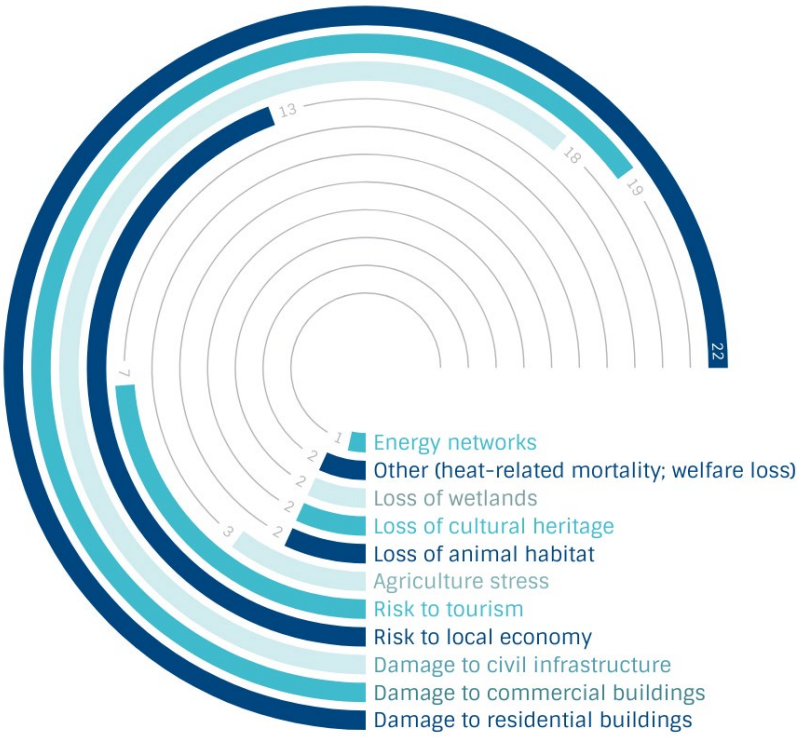

Figure 8: Climate change impacts addressed in the studies (n)

Source: Own elaboration.

d) Metrics used to assess these adaptation strategies

The evaluation of adaptation measures/strategies made in the studies applying MCA involved the use of a diverse number of criteria as indicated in the following table (**Table 16**). Amongst the different criteria, socio-economic aspects addressed, *inter alia*, implementation costs of the measures, income diversity, employment commitment, or energy savings.

Table 16: List of criteria used in studies applying MCA

Study	Category	Criteria
Van den Eynde et al. (2011)	Effect (risk reduction).	
	Technical feasibility.	
	No-regret options.	
	Ecosystem approach.	
	Multi-sectoral character of measures.	
	Urgency of implementation.	
	Institutional complexity.	
Harper et al. (2013)	Adaptation effectiveness	Severity of inundation on humans as well as buildings and community infrastructure.
	Climate uncertainty	Flexibility to respond to unexpected climate outcomes (upside / downside).
	Social and environmental impacts	i) Impact on access to coastal areas for recreation (e.g., camping, fishing, swimming).
		ii) Impact on natural coastal ecosystems.
		iii) Indirect economic / industry impacts (e.g., tourism, fishing).
		iv) Impact on cultural heritage and landscape.
	Complexity and cost	i) Capital cost.

Study	Category	Criteria
		ii) Complexity of implementation (technical, stakeholder / social, institutional).
		iii) Operating and maintenance costs.
Tonmoy et al. (2015)	Governance	i) Ease of implementation by council.
		ii) Reduction of council liability for losses associated with sea level rise.
	Social/community	i) Access to vital infrastructure (during/following storm events).
		ii) Impact on the safety of beach users.
		iii) Impact on public assets (particularly during/following storm events).
		iv) Minimizing community displacement.
		v) Overall risk mitigation.
	Financial/Economic	Maximizing the Benefit-Cost Ratio.
	Direct environmental	Impact on local natural ecological communities.
	Indirect environmental	Impact on upstream/downstream natural ecological communities.
	Aesthetics/amenity	i) Impact on the pristine visual state of the beach.
		ii) Maintaining beach width.
		iii) Beach access (to the public).
	Tourism	Impact on recreational activities.
Mostofi Camare and Lane (2015)	Economic (assets)	i) Built environment: Houses.
		ii) Built environment: Out-buildings.
		iii) Public works: Roads.
		iv) Public works: Wharf.
		v) Public works: Wells.
		Breakwater (adaptation element).
	Environmental land use (assets)	i) Residential land.
		ii) Water bodies/lake.
		iii) Greenspace/trees.
	Cultural (assets)	i) Community centre.
		ii) Church grounds.
	Social (assets)	i) Income.
		ii) People > 60 years.
		iii) Children < 14 years.
Alves et al. (2020)	Flood reduction reliability	i) High return period.
		ii) Medium return period.
		iii) Low return period.
	Cost reduction	i) Suitability (public space availability, type of roads, land use and population density, volume reduction for wastewater treatment/combined sewer overflows, sewer system type).
		ii) Land take.
		iii) Investment and maintenance cost.
	Co-benefits	i) Water quality.
		ii) Environmental (ecology/habitat creation; groundwater recharge/water reuse; air quality).
		iii) Liveability (aesthetics/amenity; urban heat reduction; community acceptability/public safety).
		iv) Economic (production capacity; energy savings).

Study	Category	Criteria
		v) Socio-cultural (educational activities; sense of community generation; recreational uses).
Baills et al. (2020)	No-regrets (existence of co-benefits) – associated with the "capacity of an adaptation measure to produce benefits regardless of the level of future climate change and even in the absence of climate change".	
	Robustness – a measure will be considered as robust if it has "capacity to be effective in the long term (several centuries), regardless of the way risks might evolve with global warming."	
	Flexible/reversible – a measure will be flexible if it "does not entail large costs if it is finally abandoned, while an irreversible measure generates significant over-costs and/or simply cannot be abandoned."	
	Short decision horizon – "short decision horizon is a measure whose implementation demands a financial commitment over less than 10 years (from the moment it is operational). Conversely, a measure with a long decision horizon is a measure that demands commitment over more than 10 years."	
	Synergy with mitigation – "reflects the impact of the measure's implementation on the overall aim of reducing greenhouse gas (GHG) emissions"	
	Immediate benefit – assessing "whether a measure is effective with respect to the management method for which it is implemented as soon as it is put in place, or if there is a delay between implementation of the measure and the associated benefits."	
	Possible impacts on other risks – considers the "indirect effects of an adaptation measure on risks for which it is not initially intended."	
	Self-sufficiency – whether measures need or not the implementation of other measures to be effective.	
	Life-expectancy – also understood as the lifetime of an adaptation measure.	
	Implementation costs and/or maintenance costs.	
Sturiale and Scuderi (2019)	Environmental	i) Air quality.
		ii) Human settlement.
	Social	i) Usability.
		ii) Multi-functionality.
		iii) Agricultural production.
		iv) Employment commitment.
	Climate	i) Reduction of temperatures.
		ii) Creation of accessible shade areas.
		iii) Therman expansion.
	Economic	i) Cost of realization.
		ii) Value of the properties.
		iii) Productive exploitation.
	Landscape	i) Quality of the landscape.
		ii) Exaltation of the seasons.
		iii) Biodiversity.
	Health and safety	i) Pollution.
		ii) Pathogenic presence.
		iii) Use of pesticides and fertilizers.
Nguyen and Bleys (2021)	Coherence	i) …with the natural conditions (soil conditions, climate conditions, local ecosystems).
		ii) …with community capacity (skills and knowledge of farmers, local experiences and local backgrounds, financial and investment capacity of farmers).
		iii) …with local customs and policies (local policies, community needs, local customs).

Study	Category	Criteria
	Efficiency	i) Economic efficiency (yield, cost of production, profits, risks, stability of input prices, stability of output market).
		ii) Social efficiency (improving the living standards of vulnerable groups, risks of increasing the gap between rich and poor people, job opportunities).
		iii) Environmental efficiency (risk of soil erosion and land degradation, risk of water pollution, risk of exhausting water sources, risk of air pollution).
	Ability to confront and adapt	i) Ability to confront (floods, droughts, and saltwater intrusion).
		ii) Ability to adapt (to recover after saltwater intrusion - SWI, crop season flexibility to avoid SWI, to confront a worsening SWI).
	Sustainability and equity	i) Sustainability (income diversity, coherence with climate change scenarios, expanding abilities, developing abilities).
		ii) Equity (proportion of farmers impacted by SWI who can access information about, and apply, adaptation options; vulnerable groups targeted by adaptation options).
Andreadis et al. (2021)	Degree of touristic activities.	
	Number and frequency of the visitors at the beach.	
	Beach accessibility.	
	Beach development.	
	Beach carrying capacity	
	Blue Flag awards.	
	Special environmental protection regime.	

Examples of monetary metrics used in the studies applying CBA were, on the cost side, the 'implementation and maintenance expenses' of the adaptation measures (approximately in 50% of the CBA examples), and the quantification of the 'expected economic damage' (direct and/or indirect losses) produced by climate change without adaptation (about 22% of reviewed CBA). On the benefit side, the 'damage avoided or reduced' with the assessed measures was often used. Moreover, the comparative analysis between costs and benefits was usually made through the indicator of benefit-cost ratio.

Studies performing 'other' types of assessments such as those developing the method of ROA expressed the costs of the adaptation strategies in terms of initial investment and avoided damage (Dawson et al., 2018; Abadie et al., 2017). Metrics used in 'Economic Impact Evaluations' did also quantify the costs in terms of expected damage (Löwe et al., 2018) and direct and indirect losses when no adaptation action was considered (Hallegatte, 2011; 2016).

e) How the adaptation strategies perform

This sub-section focuses on the **main results obtained in the reviewed studies**.

Starting by providing some examples of studies applying MCA, Nguyen and Bleys (2021) proposed five different alternatives for rice farmers to avoid saltwater intrusion in two Vietnamese farming areas. To identify the most preferred adaptation alternative, i.e., the one with the highest score, the authors combined two different ways of weighting the scores of the different criteria (coherence; efficiency; ability to comfort and adapt; and sustainability and equity): they developed a pairwise comparison matrix where they weighted coefficients and calculated consistency rates and then, ranked the alternatives with respect to the lowest subcriteria level. Two focus group supported this process to first, draw a hierarchical tree around the main problem and then, rank the alternatives

within the comparison matrices. As a result, applying the coconut-fish model was given the highest priority. This measure involved the transformation of land into canals for keeping the fishes and planting coconut trees alongside the banks to avoid saltwater intrusion.

Sturiale and Scuderi (2019) proposed MCA to evaluate citizens' perception of EBA, notably of urban green areas (e.g., uncultivated green, sport areas, urban design areas, urban parks) in Catania (Italy) and to guide the city's government on the design and implementation of new urban resilient development. The authors designed three alternative scenarios of green strategies to improve air quality and mitigate urban heat island effect (UHI): "Hypothesis 1. Inclusive – creation of green areas with inclusive and social functions (equipped with parks, urban gardens, etc.); Hypothesis 2. Resilient – creation of urban green spaces with non-usable landscape function but as a climate change adaptation measure; and Hypothesis 3. City - conservative recovery, cleaning, and maintenance of the current green." The creation of green areas and avenues, and urban gardens within the 'inclusive' strategy was the most preferred and strategic option for the choices of urban green investments.

Within **studies applying CBA or a mix of CBA and CEA**, Reguero et al. (2014) showed that beaches are natural ecosystems that contribute to coastal storm risk reduction and dissipate wave energy where waves break, stabilizing the shoreline and allowing for the development of dunes and green buffer. This study applied the Economics of Climate Adaptation framework in the US Gulf Coast to compare nature-based defences, artificial defences, and policy measures for adaptation risk reduction. The most cost-effective measures assessed were: sandbags, despite presenting a low averted damage; oyster reef restoration, with the highest benefit-cost ratio and a high averted damage; and the restoration of marshes in those areas where people and assets are most at risk. In all, nature-based defences were considered as highly cost-effective solutions.

In André et al. (2016), renaturing the beach front as a natural defence in combination with additional adaptation measures (beach nourishment, purchasing houses and business at risk or demolition of roads and networks) were found to be the most efficient hybrid strategies that included EBA solutions. This study considered five different adaptation scenarios: i) reference scenario; ii) protection; and relocation - which included iii) standard, iv) ownership, and v) leasing relocation scenarios. The 'reference scenario' only included maintenance of structures (future or existing) and beach nourishment as adaptation measures; the 'protection scenario' added riprap structures and project design, project management, and public survey to the measures of the previous scenario; and the 'relocation scenarios' included a broader list (e.g., maintenance of structures; beach nourishment; project management; purchasing housing and business at risk; incidental compensation due to property transfer taxes; demolition of buildings; demolition of infrastructure such as roads and networks; renaturing the beach front as a natural defence; and property transfer and leasing management). Results of the CBA performed in this study showed that the 'protection scenario' had a positive NPV, even though the analysis did not include the environmental consequences associated the loss of Posidonia seagrass meadows or beach areas. When integrated tourist and environmental factors in the CBA, the NPV resulted positive for the 'ownership' and 'leasing' relocation scenarios, whereas for the 'protection' and 'standard relocation' scenarios the NPV were negative.

Reguero et al. (2018) analysed three sets of interventions: nature-based measures; grey (artificial) measures; and policy measures. The results of combining CBA and CEA methods, revealed that the implementation of sandbags had the highest benefit/cost ratio (10 B/C ratio), but with lower aggregated benefit (expressed in total averted damage in billions of dollars), compared to wetland restoration in main areas at risk (8.7 B/C ratio) and oyster reef restoration (7.3 B/C ratio), both with higher aggregated benefits. On the opposite end, local levees and home elevation at high-risk priority areas show the lowest benefit/cost ratio but the highest averted damage of all measures compared.

When looking at coastal urban settings, the largest share of benefits of green infrastructure (green roofs, bioretention cells, retention, and detention ponds) was related to flood damage reduction. A CBA applied in Locatelli

et al. (2020) indicated that the NPV turned into positive after ten years of installation of green infrastructure in the city of Barcelona (Spain). Following a different methodology - SWOT analysis - Berte and Panagopoulos (2014), proposed a set of EBA to prevent flooding and mitigate water scarcity and heatwaves in the city of Faro (Portugal). These authors used a SWOT analysis "as an instrument to generate urban planning strategies". Permeable soils were proposed for run-off mitigation, but also to improve water supply. The proposed solutions for urban temperature regulation were to provide shadow streets, sidewalks and buildings planting trees on streets.

Regarding **final recommendations (including policy ones) provided in the assessed studies**, it was considered that budget oriented socio-economic analysis of adaptation strategies is a sub-optimal approach for decision making (Zhou et al., 2013). There is a need for developing exploratory forms of governance that favour learning and innovation (André et al., 2016), tools and models to help engineers, managers and policymakers on the decision-making process when ranking adaptation measures (Nguyen and Bleys, 2021; Andreadis et al., 2021; Coelho et al., 2020; Radhakrishnan et al., 2018), planning urban development (Harper et al., 2013; Sturiale and Scuderi, 2019), or comparing different adaptation strategies (Alves et al., 2020; Kuhfuss et al., 2016; Haer et al., 2018). Long-term planning perspective (André et al., 2016; Schipper et al., 2021; Lane et al., 2017) and the uptaking of flexible and dynamic adaptation strategies (Metcalf et al., 2014; Radhakrishnan et al., 2018) should be considered when developing public policies or management plans.

Any decision related to adaptation options should consider strategic (Lane et al., 2017), in-depth and careful analysis of the local and context-specific environment (Baills et al., 2020; Hallegatte, 2016; Haer et al., 2018). There is potential for different policy solutions when developing regional instead of local management strategies (McNamara et al., 2011). The design of the metrics assessing adaptation options could be more robust if it is used a multi-method approach to formulate more precise assessment objectives (van der Pol et al., 2021). When evaluating adaptation strategies, it should be integrated scenario-based cost–benefit analyses (or delayed investment CBAs) with adaptation pathways into their frameworks (de Ruig et al., 2019; Scussolini et al., 2017) together with an evaluation of the environmental impact of the planned interventions before implementation (Ritphring et al., 2021).

Other examples of recommendations include the need to improve research. In relation to adaptation strategies, further effort is needed in developing strategic analysis (Lane et al., 2017), targeting other potential drivers of individual vulnerability (e.g., education and pre-existing medical conditions) and of institutional adaptive capacity (e.g., effectiveness of early warning systems and inter-agency cooperation) (Rohat et al., 2021). Moreover, the policy making process will potentially benefit from the following research objectives: the analysis of the feasibility and acceptability of the different adaptation options for the local population (Hérivaux et al., 2018); the integration of long-term perspective and multidimensional nature of climate change in decision-making tools (André et al., 2016); the better understanding of the impact of SLR on coastal ecosystems (e.g., groundwater, beaches and dunes, lagoons and wetlands); and further research about the development and effectiveness of ecosystem-based adaptation strategies (Hérivaux et al., 2018).

Research recommendations are related to the exploration of the precise mechanisms by which SLR risk affects insurance rates, immigration and emigration patterns, financial investments in infrastructure, and the economic activity in coastal regions; the inclusion of predictive variables in heat risk models to assess a wider range of adaptation strategies (Rohat et al., 2021); or the development of a probabilistic model that combines SLR and population migration. The later would require determining if sufficient data exist to probabilistically evaluate potential patterns of migration (Bloetscher et al., 2016; de Ruig et al., 2020). Further assessment of socio-economic inequalities derived from the different adaptation options implemented with different methods other than CBA (Zhou et al., 2013) are also stepwise knowledge recommendations.

CONCLUSIONS

This deliverable summarises the work developed in task 7.1 - "Analysis of socio-economic assessment methods, databases, and studies addressing EBA and other adaptation strategies". The socio-economic valuation and assessment methods analysed in this deliverable, as well as the adaptation strategies identified, will support the development of participatory and expert-based evaluation and prioritization of the different SCORE interventions. This is closely linked with the upcoming WP7 tasks: T7.2 (Development of a methodological framework for the socio-economic assessment of adaptation measures to climate change); T7.3 (Participatory socio-economic assessment of EBA interventions); and T7.4 (Expert-based socio-economic assessment of EBA interventions). Moreover, the set of policy recommendations provided by some of the reviewed studies will also be inspirational for Task 7.5 – "Policy recommendations to assist decision making in climate change adaptation at the local, national and EU level".

The following paragraphs will go through the main highlights of the sections of this report, establishing connections with the upcoming tasks of WP7:

Section 1. Introduction

- Coastal areas are highly vulnerable to several climate change impacts such as SLR, flooding, erosion, saltwater intrusion, or storms. Depending on the impacts prioritised in the different coastal city living labs (CCLLs), WP7 will have to incorporate climate change scenarios in the development of the socio-economic assessment of EBA and other adaptation strategies, particularly in T7.3 and T7.4. For this purpose, connection of WP7 with WP1 (Mapping the baseline exposure and risk of extreme climate impacts on coastal cities), WP4 (Regional and local projections, analyses, modelling and uncertainties), and WP5 (Pre/post-EBA interventions evidence collection and knowledge marketplace) will be of particular importance.
- It is essential to stimulate climate change adaptation in these coastal areas. Adaptation can either be proactive/anticipatory or reactive to impacts; planned as a result of a deliberate policy decision or autonomous, which can be driven by self-interest; or incremental or transformational, the former maintaining the essence and integrity of a system or process, and the latter, changing the fundamental attributes of a system in response to climate change. The rationale behind the development of past, present, and future adaptation actions will certainly be a topic of interest in the CCLLs. It will be interesting to analyse how policies are formulated, implemented, and evaluated, and how the different stakeholders are involved in these processes. These objectives could fall under the scope of T7.5 (Policy recommendations).
- Adaptation measures can be categorized in different ways. This literature review followed the classification of hard (more relying on engineering-based solutions), soft (e.g., initiatives encouraging adaptation behaviour or focusing on coastal management and regulation), EBA (green-oriented measures more relying on interventions implemented at the ecosystem level), and hybrid (resulting from the mix of the previous solutions) adaptation strategies. The upcoming tasks of WP7 will focus more on the analysis of EBA, although it will also be important to compare their socio-economic evaluation with other types of adaptation.
- The fields of Environmental and Ecological Economics provide several methods at our disposal that allow to valuate and evaluate the implementation of adaptation measures. Section 1 presented several market and non-market approaches for economic valuation, methods for the evaluation and for the support of the decision-making process, as well as the concept of ecosystem services and its potential analysis through various available tools. This wide set of tools will be under consideration for the upcoming tasks of WP7.

Section 2. Systematic literature review of socio-economic assessment studies applied to climate change adaptation

The following points will summarise the main findings for the four general research questions underlying the systematic literature review:

1. What socio-economic assessment methods have been used to analyse adaptation strategies?

- Results showed that CBA was applied in 45% of the reviewed studies. The remaining studies implemented MCA, MCA/CBA, CBA/CEA and other methods such as System Dynamics modelling, risk assessment or ROA. About 41% of the studies were participatory-oriented analyses, with a significant part of these relying on MCA or its combination with CBA. Based on these results, both CBA and MCA are considered as two potential options for the socio-economic assessment of EBA and other adaptation options in upcoming tasks 7.2 to 7.4. Amongst potential benefits of using these methods, CBA, and particularly its extension - social CBA (SCBA) - can be used to compare the cost-benefit ratios of the proposed solutions in a clear way, incorporating not only economic financial aspects of the assessed projects but also social and environmental effects. Regarding MCA, it favours the involvement of stakeholders in the evaluation of social and economic dimensions of EBA through a wide set of criteria that may include monetary but also non-monetary indicators.

2. In which adaptation context have these assessment methods been utilized?

- Flooding and SLR were the most common climate change hazards addressed in the studies. Still, most of the assessments focused on multi-hazards, which included the previous two hazards along with others like storm surge or coastal erosion. Damage in residential and commercial buildings, as well as on civil infrastructure were the most important climate change sectoral impacts. WP7 and SCORE in general, will have to consider the challenge behind understanding the non-linear interactions occurring between several hazards and impacts.
- Most of the studies addressed hybrid adaptation solutions, i.e., combined hard, soft and/or EBA strategies. Dike construction and heightening of seawalls were some frequent examples of hard measures, which were also often combined with sand nourishment and wetland restoration for flooding avoidance. Construction of pumping stations and infiltration trenches were other measures proposed to face intense rainfall events and flooding hazards. Floodplain zoning, early warning systems or the increase in the access to health care were some examples of soft solutions. Regarding EBAs, the reviewed studies focused on wetland's restoration, rehabilitation of mangrove forests and restoration of barrier and oyster reefs, among others. This portfolio of adaptation measures will be accessible for local and regional stakeholders, notably during the identification and selection of potential solutions for each CCLL.

3. Which monetary and non-monetary metrics have been used to assess these adaptation strategies?

- Examples of metrics used in the reviewed studies included, inter alia, the indicator of benefit-cost ratio, which was applied in a significant part of CBA examples, or monetary estimates of direct and indirect losses due to the impact of climate change, and of economic benefits associated with avoided damages. The MCA studies presented a diverse list of social, economic, and environmental indicators that can be discussed by local and regional stakeholders of SCORE CCLLs, either in a preliminary identification of potential adaptation solutions for their specific context, or the evaluation of planned or implemented measures. Besides MCA, other types of methods applied non-monetary indicators. These included the adaptation effectiveness index, to measure the degree (high, medium, low) of adaptation of population to heat events, or the natural hazard vulnerability index, which relates the probability of a hazard to occur to the exposure of population to the hazard, among others.4. How do these adaptation strategies perform?

- Wetland's restoration, rehabilitation of mangrove forests and restoration of barrier and oyster reefs were found to be efficient for mitigating coastal erosion, SLR, flooding, and pluvial risks. Within the urban context, the

installation of green roofs in buildings, planting trees to shadow streets and buildings, or the increase in urban green areas were pointed as good solutions to favour urban climate control, mitigating extreme heat events and heat island effects. Some studies expressed the potential of green infrastructure to increase biodiversity, improve air quality and to play an important social role by favouring interaction and cultural and recreational activities, among others.

- Different assessment methods (CBA, CEA, Economics of Climate Adaptation framework) identified sandbags as a cost-effective measure, though benefits averted were very low. Oyster reef restoration, marshes and wetland restoration performed much better when risk reduction was seen as priority criteria for the evaluation of adaptation. Once the restoration is implemented, these EBA present low maintenance costs, thus resulting in cost-effective solutions.
- Despite the potential cost-effectiveness of some hard measures like the construction of defence infrastructure, when considering stakeholder consultation, this type of measures occupied a lower position in ranking priorities in comparison with EBA solutions. Environmental and social co-benefits of green infrastructure and restoration of natural ecosystems were prioritized by actors in every participatory approach analysed.
- Examples of recommendations provided in the reviewed studies included the suggestion of implementing of hybrid strategies to lower future uncertainty risks (Du et al., 2020); the need for decision-makers to use the results of the adaptation strategies analysis when developing policies and plans (Harper et al., 2013; Alves et al., 2020; Sturiale and Scuderi, 2019; Nguyen and Bleys, 2021; Andreadis et al., 2021; Kuhfuss et al., 2016); or the potential improvement in the assessment of socio-economic inequalities by using different methods than CBA, which capture different social dimensions through other quantitative/qualitative indicators (Zhou et al., 2013). As mentioned before, policy recommendations provided by the reviewed studies will support the development of T7.5.

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APPENDIX 1. SUMMARY OF SELECTED REFERENCES IN THE SYSTEMATIC REVIEW

Table A 1. Summary of the main characteristics of the reviewed studies[8]

ID	Study	Type of publication	Geographical Scale	Geographical location(s)	Assessment method	Aim of the assessment	Stakeholders involved in the analysis	Type of adaptation strategies addressed	Climate hazards addressed	Results of the assessment (examples)	Final recommendations provided, including policy recommendations (examples)
1	Van den Eynde et al. (2011)	Report	Regional/ provincial	Belgian Part of the North Sea (Belgium)	MCA/CBA	To determine and evaluate the effects of climate change and possible adaptation scenarios in the North Sea, both on a regional and sectoral scale (coastal defence, coastal tourism, fisheries).	Citizens and citizens groups, public authorities, researchers/academicians, private sector.	Hybrid (e.g., artificial islands, flood insurance, dikes).	Multi-hazards (temperature increase, storminess/extreme weather conditions, SLR, flooding, coastal erosion).	Based on the MCA and stakeholder consultation, weather forecasting tools, preparedness of marinas, beach nourishment and road pricing represent adaptation measures with a high potential of success for the coastal tourism sector.	The adaptation measures proposed in the different case studies were all subjected to a legal and policy evaluation.
2	Harper et al. (2013)	Others – conference paper	Regional/ provincial	Townsville regional community, Far North Queensland (Australia)	MCA/CBA	To evaluate potential practical coastal adaptation strategies to respond to existing and future threats from coastal hazards in the region.	Citizens and citizens groups, public authorities, researchers/academicians, private sector.	Hybrid (e.g., regeneration of dunes, engineering solutions for flood control, raising land levels, land use change).	Multi-hazards (SLR, flooding, coastal erosion, storm tide events).	"The results identified regions likely to be affected by high coastal hazards. The study shows that the 'optimal' timing of adaptation for some districts may be much sooner than otherwise anticipated (e.g., prior to 2030)."	"The results are expected to be used for informing decision making in the preparation of the new Council planning scheme, infrastructure plan, and asset management plan."
3	Tonmoy et al. (2015)	Others	district/neighbourhood/street	Callala beach, Shoalhaven, New South Wales (Australia)	MCA/CBA	To rank a set of local-scale adaptation actions and assist in decision making.	Stakeholders involved but not specified.	Hybrid (e.g., seawall, beach nourishment, groynes).	Multi-hazards (SLR, flooding, erosion).	"Results show that, in general, a combination of beach nourishment & groynes is the most preferred option for Callala beach, across all decision analysis methods. Our analyses also show that hard measures such as sea walls tend to perform better in cost-benefit analyses where non-monetary factors such as community preferences, aesthetics and environmental factors are omitted. On the other hand, including these factors through MCDA methods seems to push sea walls down the rank."	No further recommendations included.

[8] Full information about the results is available upon request to the authors Luís Campos Rodrigues (lcampos@ent.cat) and Mar Riera Spiegelhalder (mriera@ent.cat).

ID	Study	Type of publication	Geographical Scale	Geographical location(s)	Assessment method	Aim of the assessment	Stakeholders involved in the analysis	Type of adaptation strategies addressed	Climate hazards addressed	Results of the assessment (examples)	Final recommendations provided, including policy recommendations (examples)
4	Mostofi Camare and Lane (2015)	Article	District/ neighbourhood/ street	Coastal community of Little Anse, Isle of Madame, Nova Scotia (Canada)	MCA	To evaluate adaptation decision options and the development of measures for vulnerability and adaptive capacity.	Citizens and citizens groups, public authorities, researchers/academicians, private sector.	Hybrid (e.g., road build up, breakwater).	Multi-hazards (flooding, storms, and storm surges).	"The results indicate that, in the case of Little Anse, the strategic decision to protect the community by a new breakwater arm provides preferred measures for resilience and adaptive capacity."	No further recommendations included.
5	Alves et al. (2020)	Article	Urban/ peri-urban	Dutch side of the island of Sint Maarten (Caribbean Netherlands)	MCA	To compare among green-blue, grey and hybrid strategies for flood mitigation and how it changes if considering co-benefits.	Citizens and citizens groups, public authorities, researchers/academicians, private sector.	Hybrid (e.g., open detention basis, rainwater barrels, pervious pavements).	Flooding	Results stress the importance of considering the co-benefits as a central objective when selecting flood mitigation options.	'The authors "recommend the application of this type of multifunctional and multisystem assessment to support urban sustainability planning. It allows a broad and reliable comparison of diverse green-blue-grey solutions and its multiple benefits."
6	Baills et al. (2020)	Article	Regional/ provincial	Aquitaine region (France)	MCA	To provide an initial assessment of measures to adapt to coastal risks regardless of the study site.	Experts (not specified).	Hybrid (e.g., wetland restoration, beach access management, temporary storm surge dams, cliff drainage).	Multi-hazards (coastal flooding, erosion).	The study emphasises the need to implement some of these measures as soon as possible. About 86% of the measures investigated generate immediate benefits.	Any decision on adaptation measures cannot only rely on this assessment results. It must take context into account for an in-depth assessment.
7	Sturiale and Scuderi (2019)	Article	Urban/peri-urban	Catania (Italy)	MCA	To classify alternative scenarios based on the preferences of individual groups based on certain decision criteria.	Citizens and citizens groups, public authorities, researchers/academicians, private sector.	EBA (e.g., creation of green areas such as urban gardens).	Other (air quality, and urban heat island – UHI).	The study suggests the potential for MCA in the governance of green spaces based on its ability to integrate ecological, social, and economic values along with different stakeholder preferences. Furthermore, the tool supports the incorporation of GIs in urban planning, making it a valid instrument for achieving the objectives of realizing resilient and inclusive cities.	The proposed methodology consisted of integrated approach of participatory planning and social multi-criteria to guide the cities development.
8	Nguyen and Bleys (2021)	Article	Regional/ provincial	District of Duy Xuyen, Quang Nam province & District of Quang Dien, Thua Thien Hue province (Vietnam)	MCA	To rank the potential adaptation options for rice farmers, considering sustainability criteria.	Citizens and citizens groups, public authorities, researchers/academicians, private sector.	EBA (e.g., switch to new plantations/food production).	Other (saltwater intrusion).	"Sustainability and equity" was considered the most important category in the MCA. 'Sustainability' was linked with the indicators of income diversity, coherence with climate change scenarios, expanding abilities, developing abilities, whereas 'Equity' was analysed through the indicators of proportion of farmers impacted by seawater intrusion who can access information about, and apply, adaptation options; and vulnerable groups targeted by adaptation options. Moreover, stakeholders focused more on	The analytic hierarchy Process (AHP) followed in the MCA has proven to provide a solid scientific basis for policy makers to rank the adaptation measures.

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										long-term strategies when tackling climate change issues.	
9	Andreadis et al. (2021)	Article	District/ neighbourhood/ street	Komi Beach, Chios island, North Aegean sea (Greece)	MCA	Evaluation of socio-economic significance of beaches and their vulnerability to SLR and the design of effective adaptation measures.	Researchers/ academia.	Hybrid (e.g., beach elevation increase, beach nourishment).	Coastal/beach erosion.	"The results show that nourishment with material of larger grain size can significantly reduce nourishment costs. Sediments with greater grain size are also less prone to sediment mobilization and transport and, thus, could enhance beach resilience. Nourishment filling material with grain sizes similar to the native beach material might be preferrable with regard to the beach bio-geological composition and aesthetics."	"The proposed framework can provide users primarily coastal managers and relevant governance institutions a better understanding of the challenges posed by beach erosion in island settings as well as prioritization of adaptation responses, efficient resource allocation and a roadmap for effective adaptation."
10	Kuhfuss et al. (2016)	Article	Regional/ provincial	Languedoc-Roussillon region (France)	Other – Economic impact evaluation.	Evaluation of the impacts of coastal inundation on ecosystem services production.	Researchers/ academia.	Hybrid (adaptation strategies – denial; laissez-faire; and strategic retreat of infrastructure and buildings).	SLR	The study demonstrated that "strategic retreat" would halve the damages resulting from submersion.	This assessment supports public policies by allowing different adaptation strategies to be compared. It points out that policies of this type are socially difficult to accept and institutionally difficult to organize. It is important first to demonstrate their interest and undertake information and awareness-raising actions.
11	Hallegatte (2016)	Book Chapter	Urban/peri-urban	Mumbai (India)	Other – Economic impact evaluation.	To assess the vulnerability to heavy precipitations of the city of Mumba and estimate direct and indirect losses.	None.	Hard (upgrade in the drainage system and an increase in building quality).	Multi-hazards (heavy precipitations and extreme run-offs).	The losses due to a 100-year event can be reduced below their current level. An increase in hazard does not need to translate into more disasters if adequate measures are implemented.	"It would be particularly beneficial to start immediately to develop careful assessments of adaptation options, with local, context-specific information so as to design and implement adaptation and risk management plans in coastal cities. Such plans should integrate climate change considerations within routine urban land-use and infrastructure planning."
12	McNamara et al. (2011)	Article	Regional/ provincial	A populated cuspate coastline broadly similar to the Carolina coast (USA).	CBA	Explore the impact of an observed increase in hurricane-generated waves on shoreline evolution along a populated cuspate coastline.	Public authorities.	Hybrid (coupling shoreline nourishment with coastline changes arising from wave-driven alongshore sediment transport and erosion related to sea level rise).	Coastal erosion	Coastal response to changes in forcing differs dramatically depending on the nature of the interaction between patterns of landscape change and economic patterns.	The paper results suggest that regional management strategies could alter the rate of resource depletion, perhaps allowing more time for development of new technologies that could make new sources of sand economically viable.
13	Haer et al. (2018)	Article	Regional/ provincial	Regions of Mexico	CBA	To assess current and future levels of risk of both coastal and	None.	Hybrid (e.g., dykes, floodplain	Flooding	Under constant climate conditions, about half of the states require investments in	"The precautionary approach may be preferred by risk-averse policy makers, while the no-regret approach

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						riverine flooding for all states of Mexico, and costs and benefits of increasing flood-protection standards.		zoning, beach nourishment or realignment).		additional protection to achieve or uphold economically optimal protection standards (standards for coastal floods are significantly higher than those for river floods).	by policy makers who expect small and gradual increases in flood risk as a result of climate change."
14	Coelho et al. (2020)	Article	Regional/provincial	Northwest coast (Portugal)	CBA	Assessment of COMASO (coastal management software), a sequence of coastal modelling tools for coastal management and planning.	Researchers/ Academicians.	Hybrid (artificial nourishments, groins, longitudinal revetments, and detached breakwaters).	Coastal erosion	COMASO tools can help giving answers to the major problems of the coastal planning and management entities, integrating transversal knowledge in risk assessment, physical processes, engineering, and economic evaluations.	"It is considered important to easily map coastal erosion vulnerabilities and risk, and related climate change effects since it offers means to put preventive measures in place. A method to identify and highlight the priorities of intervention in a simple and low data demanding process is highly valuable in the coastal management process."
15	Ritphring et al. (2021)	Article	Regional/ provincial	Pattaya beach and Chalatat beach (Thailand)	CBA	To compare the adaptation measures to sea level rise.	None.	Hybrid (beach nourishment, seawall, and setback).	Multi-hazards (sea-level rise, coastal erosion, storm surge).	The Benefit-Cost ratio of seawalls is smaller than that of beach nourishment. The analysis suggests that it is worth implementing beach nourishment to mitigate against the effects of climate change. On the other hand, it is necessary to evaluate the environmental impact assessment and sand resources before the implementation of beach nourishment. Benefit-Cost ratio of setback shows that it is not worth retreating when the sea level is rising.	"The monitoring of impacts from beach nourishment projects ought to be carried out cautiously. The results will be useful in the process of preliminary decision making for the policymakers."
16	Hallegatte et al. (2011)	Article	urban/peri-urban	City of Copenhagen and the centre of the Swedish-Danish Oresund region (Denmark)	Other – Economic impact evaluation.	Assess the economic impacts of sea level rise and storm surge risk and the benefits of adaptation.	None.	Hard (dikes, sea walls).	Multi-hazards (SLR and storm surge).	Copenhagen is not highly vulnerable to coastal flooding today due to its high standards of defence. Without protection, SLR significantly increases the risk of flooding	Authors found crucial: "Faultless maintenance, improvement of emergency plans, early warning and evacuation schemes, and disaster preparedness and organization, land-use and urbanization plans that make sure additional people and assets are not put at unacceptable level of risk." "Mitigation policies can also aid adaptation by limiting the pace of future sea level rise."
17	Locatelli et al. (2020)	Article	urban/peri-urban	Barcelona and Badalona (Spain)	CBA	Evaluate the socio-economic viability of selected Green Infrastructure applied to two different case studies.	Multi-stakeholder (not defined).	Hybrid (green roofs, bioretention cells and retention and detention basins, permeable pavements, and infiltration trenches).	Multi-hazards (flooding, combined sewer overflows).	The largest share of GI benefits in Barcelona was from reduced flood damages (56%), while in Badalona was from additional benefits like added value of properties and habitat provision (89%).	No recommendations included.

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18	Haer et al. (2017)	Article	Regional/ provincial	state of Tabasko (Mexico)	CBA	To provide insights for identifying economically efficient adaptation strategies to manage natural disaster risk (riverine and coastal flooding).	None.	Hard (river and coastal dike infrastructure).	Flooding	Investing in dike structures is economically attractive; increasing riverine protection standards is economically desirable for all protection standards under future climate conditions; under both climate change scenarios, it would be economically rational to raise protection standards (100 years at least).	The safe policy strategy could be to follow the high-SLR scenario in the design of flood protection infrastructure; adaptation strategies need to extend beyond flood protection infrastructure; more refined local analysis is needed to guide local adaptation planning.
19	Oanh et al. (2020)	Article	Regional/ provincial	Vietnamese Mekong River Delta (VMRD). (It includes Can Tho city, seven coastal provinces ranging from Long An to Kien Giang, and five other provinces).	CBA	To evaluate inundation impacts and the economic damage resulting from SLR, and identify the effectiveness of mixing grey and green infrastructures.	None.	Hybrid (sea dikes, mangrove forest rehabilitation).	Flooding	The CBA showed that the benefits of adaptations can be much higher than the costs for all adaptations under all socio-economic scenarios. The combination of sea dikes and mangrove forests has the highest NPV among all the adaptation options. The system has been proved to be suitable to develop the adaptation strategy in the VMRD.	No recommendations included
20	Tsvetanov and Shah (2013)	Article	urban/peri-urban	Connecticut (USA)	CBA	To determine the optimal timing of initiating protection that maximizes expected net benefits.	None.	Hybrid (seawalls, land elevation, setback lines)	Multi-hazards (SLR and coastal storms).	The model reveals optimal timing of initiating protection measures could vary across regions and that the exact timing pattern may be sensitive to discounting, maintenance costs, as well as additional social costs, such as environmental and amenity losses resulting from the presence of “hard” structures. If possible negative environmental and aesthetic impacts of sea barriers are taken into account, delaying protection would become more desirable, with the extent of delay being sensitive to the relative magnitude of one-time costs (e.g., loss of ocean view and recreational opportunities) vs. continuous costs (e.g., shoreline erosion and loss of wetlands).	No recommendations included.
21	van der Pol et al. (2021)	Article	Regional/ provincial	249 prespecified floodplains in German Baltic Sea coast (Germany)	CBA	To show that combination of CBA and methods for robust decision-making can narrow down the range of acceptable and efficient solutions.	None.	Hybrid (dikes, dunes, floodwalls).	Flooding	The CBA suggests areas that might need for investment in defences for flood protection, however, provides limited guidance on the choice of risk-based flood defence heights due to the differences in efficient size of current and future investments across scenarios.	Policy implications: the need to address investment backlogs and increase investment preparedness in the face of SLR; "If decision-makers can agree on some general definition of robustness, for example low regret, then the implications of related robustness metrics can be clarified quantitatively with a multi-method

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											approach to formulate more precise objectives."
22	Zhou et al. (2012)	Article	urban/peri-urban	Odense (Denmark)	CBA	To provide important information for decision making on how to best adapt to urban pluvial flooding due to climate impacts in cities.	None.	Hard (e.g., pipe enlargement, and relief channels; flood proofing; dams; flood walls).	Flooding	The method presented is an important decision support tool for climate adaptation for urban drainage design and can be applied for the analysis of other adaptation strategies.	All examined adaptation options are similar in terms of monetary results, but their socio-economic inequalities need to be further assessed, potentially through a different method than CBA.
23	de Ruig et al. (2020)	Article	urban/peri-urban	Los Angeles (USA)	CBA	To offer policymakers insight into economically optimal strategies for adapting to SLR.	None.	Hard (elevation of buildings and roads, storm surge barriers, dikes underneath beaches).	Multi-hazards (SLR and flooding).	Assessment shows an increase in the number of buildings at risk of flooding and erosion for each sea level rise scenario examined	Importance of scales and data availability. The design of more effective communication strategies to homeowners is needed and further suggested.
24	Abadie et al. (2017)	Article	urban/peri-urban	62 main coastal cities in Portugal and Spain	CBA	To estimate potential economic damage of no adaptation actions and the investment cost of implementing adaptation strategies.	None.	Hard (building defences).	Flooding	Bilbao, Valencia and Barcelona are the coastal cities with the largest expected accumulated damage in the case of inaction. adaptation costs in the long term are much smaller than the increasingly expensive costs of inaction, and thus, investing in adaptation is a good decision when comparing costs and benefits of the actions. Not adapting to climate change is not, by any means, a good strategy in the medium and long term.	Importance of the need to implement both mitigation and adaptation policies. Not accounting for the full distribution of sea level rise as well as damage costs is a clear and very significant underestimation of climate risks that may lead to inadequate policy decisions.
25	Fletcher et al. (2016)	Article	urban/peri-urban	six case study communities spread along the Australian coast	CBA	To calculate measures of economy, equity, and affordability for three types of adaptations.	Public authorities.	Hybrid (sea wall, changed minimum floor height, and retreat).	Flooding	Many households faced little risk of inundation. "Each type of adaptation protects different numbers of properties, and each requires engagement and consensus at different scales in the community to successfully implement." "The framework is focused on decision making at the local government level."	"Specific infrastructure projects undergoing benefit–cost analysis could incorporate some analysis of the distribution of costs and benefits."; "Where there is an economic argument for adaptation at the case study level, the distribution of risk throughout the community should be assessed."
26	Radhakrishnan et al. (2018)	Article	urban/peri-urban	Elster Creek catchment in Melbourne (Australia)	CBA	To incorporate and evaluate flexibility into adaptation measures for managing flood risk.	Stakeholders involved, but not specified.	Hybrid (e.g., road elevation, foreshore mangrove, rainwater harvesting tanks, wet proofing houses, drainage retrofitting).	Multi-hazards (frequent and intense rainfall events and SLR).	A combination of measures, especially rainwater harvesting and flood proofing, yields a better cost – benefit ratio across all the scenarios. Detention at household or local level, using property level flood proofing measures, is effective against flooding by attenuating peak discharges of extreme rainfall events.	"The future generation will benefit from the flexibility of making their own choice of choosing and implementing adaptation measures at that point in time, as their choices will not be bound or restricted by large scale infrastructure measures that were carried out in the past."

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27	Scussolini et al. (2017)	Article	urban/peri-urban	Ho Chi Minh City (Vietnam)	CBA	To quantify the effectiveness of several adaptation measures aimed at reducing flood risk and to evaluate their economic performance and social suitability.	None.	Hybrid (e.g., dike; modify land elevation; land use change).	Flooding	Despite the ring dike shows the lowest B/C, it is not an effective measure across all scenarios and horizons if entire city is considered. Elevating parts of the city can be effective in reducing annual damages for the whole city, but its effectiveness varies depending on the city area. "Dry proofing urban and rural houses and small businesses is highly effective in reducing annual damage". Combining elevation and dry proofing yield greater benefits.	"The adaptation pathways analysis can illuminate decision-making, in the short and long term" "A flood-wise land use plan should be developed, gradually enforcing the removal of exposed assets and people from risky low-lying areas. The option of building a ring dike may still be considered socially desirable, but the consequences for the outer parts of the city would need to be addressed by complementary measures"
28	WBCSD (2014)	Report	Regional/ provincial	U.S. Gulf Coast: Texas, Louisiana, Mississippi, and Alabama; Gulf of Mexico	CBA	To evaluate different alternatives for strengthening improvements of electricity infrastructure.	None.	Hybrid (e.g., improve building codes; beach nourishment; wetlands restoration; levee systems; improved standards for offshore platforms).	Multi-hazards (extreme temperatures, flooding, SLR, storms, wind damage, and storm surge).	Both in the case of US Gulf coastland the case of Gulf of Mexico, investment in the most cost-efficient adaptation measures identified can reduce approximately $7 billion per year in annual expected loss avoided to 2030.	Regulations may need adapting to the potential impacts and uncertainty of climate change and utilities may need to adapt to retain public support and their “license to operate.” "Regulation also needs to support a viable business model, including incentives to utilities to invest in adaptation."
29	Vousdoukas et al. (2020)	Article	Regional/ provincial	About 10,000 coastal sections of the European coastline, as well as at NUTS2[9], country and European level	CBA	Quantify the rise in coastal flooding damages unless mitigation and adaptation measures are taken.	None.	Hard (dyke construction and rising dyke height).	Multi-hazards (SLR and flooding).	Benefits tend to outweigh costs in areas where population density is larger than 500 people per km2. "Local studies are also more appropriate to evaluate the co-existence of hard protection with other adaptation practices, such as nature-based solutions, retreat or accommodate."	"Considering longer time spans, the benefits and maintenance costs of rising dyke heights are therefore likely much higher than estimated in this paper." "Our analysis does not exclude the parallel implementation of more sustainable environmental practices to enforce the physical and ecological resilience of coastal zones"
30	Zhou et al. (2013)	Article	urban/peri-urban	Urban catchment of Risskov, Aarhus (Denmark)	CBA	Comparative assessment of adaptation schemes to help decision-makers select the appropriate adaptable solution.	None.	Hybrid (e.g., pipe enlargement; Open Urban Drainage Systems - OUDS; green spaces in the urban landscape).	Flooding	All investigated adaption strategies are economically beneficial relative to the laissez-faire strategy. The results show preference for OUDS. It has positive impacts on recreational and environmental aspects in urban context, so it can be considered as a replacement for traditional drainage solutions.	"A budget oriented socio-economic analysis was found to be a sub-optimal approach for decision making as it will be blind to the potential additional services provided by non-market goods linked with some adaptation scenarios."

[9] The Nomenclature of territorial units for statistics (NUTS) is a hierarchical disaggregated classification of EU and UK regions. NUTS level 1 corresponds to the “major socio-economic regions”, NUTS 2 to “basic regions for the application of regional policies”, and NUTS 3 to “small regions for specific diagnoses”. In: https://ec.europa.eu/eurostat/web/nuts/background.

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31	Wagenaar et al. (2019)	Article	urban/peri-urban	Colombo (Sri Lanka)	CBA	Application of cost-benefit analyses for decision making on public investments for flood risk management.	Citizens and citizens groups.	Hard (e.g., widening of locks; a tunnel to discharge water; a new pumping station).	Flooding	Factors as risk aversion, income distribution and social welfare are not considered in the analysis. This means measures are mostly aimed at wealthier areas. The analysis considers socio-economic and land-use changes, but it does not consider climate change, which underestimates the future flood risk and therefore the benefits of the measures are likely to be higher. The "effect of stopping wetland encroachment is much larger than the effect of the structural adaptation measures."	"Climate change is a more important factor for areas that have less urgent problems, or when a lower discount rate is applied. Therefore, it might be useful to take climate change into account for similar studies in the future."
32	Du et al. (2020)	Article	urban/peri-urban	Shanghai (China)	CBA	Analyse the costs and benefits of several adaptation strategies to reduce flood risk.	None.	Hybrid (e.g., storm surge barrier; floodwalls; enhance building codes for individual properties, including wet-proofing, dry-proofing; and building elevation, 'wetland' strategies).	Flooding	"Among the two hard strategies, the barrier strategy has better performance in terms of both the benefit/cost ratio and the NPV. Among the soft strategies, the wetland strategy has a higher benefit/ cost ratio and a higher NPV than the wet-proofing strategy. The cumulative benefits can pay off the total costs (i.e., the initial investments and maintenance costs) much earlier using the soft strategies than using the hard strategies." The hybrid strategy lies in between the values of the hard and soft strategies, as so in terms of the payoff period.	"A hybrid strategy that combines the elements of hard strategies and soft strategies outperforms both single-strategy approaches in terms of lower future risk and higher benefit/cost ratios. The hybrid strategy can serve as a robust flood adaptation strategy for Shanghai."
33	He et al. (2020)	Article	Regional/ provincial	Pearl River Delta (China)	CBA	To evaluate the efficiency of adaptation strategies for different scenarios and compare projects that provide the greater net benefit.	None.	Hard (dikes).	SLR	"The protection strategy of heightening the dikes should be adopted in response to future sea level changes and storm surge events. The largest loss happens in 2100 in a 100-year return period storm surge if no adaptation is adopted"	No recommendations included.
34	de Ruig et al. (2019)	Article	Regional/ provincial	Los Angeles county (USA)	CBA	To provide insights in the individual economic efficiency of the strategies and the timing of investment.	None.	Hybrid (e.g., beach nourishment; elevation of buildings; highway elevation; breakwater; wet flood proofing).	SLR	The scenario-based CBA highlight the necessity of early adaptation. If adaptation pathways instead of single adaptation strategies are implemented, economic efficiency can improve up to 10% in net-present values	"We recommend that studies evaluating adaptation strategies should integrate scenario-based cost–benefit analyses (or delayed investment CBAs) with adaptation pathways into their frameworks."

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35	André et al. (2016)	Article	Urban/ peri-urban	A fictional site that constitutes an archetypal example of a seaside community of the French Mediterranean coastline.	CBA	Assess the costs and benefits of a territorial project of urban development.	None.	Hybrid (e.g., riprap structures; beach nourishment; purchasing housing and businesses at risk; demolition of infrastructure; renaturing the beach front).	Flooding	The results of enhanced CBA that integrate tourist and environmental factors show positive NPV for relocation scenarios with include measures as division of ownership or buy and leaseback.	"Decision-making tools must evolve to integrate the notion of long term and the multidimensional nature of climate change."
36	Reguero et al. (2014)	Others	Regional/ provincial	Gulf of Mexico (USA)	CBA/CEA	To evaluates the cost effectiveness of adaptation options to estimate possible large-scale coastal adaptation alternatives.	None.	Hybrid (e.g., wetland restoration; levees; sandbags; floodwalls; barrier island restoration; oyster reef restoration; beach nourishment; home elevation).	Multi-hazards (tropical storms and SLR).	"Nature-based defences are highly cost effective in both scenarios under conservative and less conservative estimates of cost and effectiveness." "The combination of major oyster reef and marsh restoration can avert billions of dollars in future damages2	"Nature-based defences are likely to provide their most important benefits for high frequency, low intensity events from daily to events of intermediate frequency and intensity. They thus can make the coastal zone more resilient to frequent storms."
37	Metcalf et al. (2014)	Article	Regional/ provincial	St Helens in south-east, Tasmania (Australia)	other	To predict the effects of change and identify potential adaptation strategies.	Citizens and citizens 'groups; public authorities; private Sector.	Soft (fisheries management).	Others – ocean warming temperatures.	"Methods such as those undertaken in this study can facilitate this awareness and act as a springboard to the uptake of flexible and dynamic adaptation strategies."	"Communities and policy-makers can benefit from these and similar methods that may aid the assessment of their own adaptation needs without a full-blown quantitative investigation and can be used to stimulate further discussion and ideas."
38	Bloetscher et al. (2016)	Article	Regional/ provincial	Southeast Florida region: counties of Broward, Miami-Dade, Palm Beach, and Monroe (USA)	other	To develop a long-term planning framework to adapt to SLR and protect vulnerable infrastructure.	Stakeholders involved, but not specified.	Hybrid (e.g., infiltration trenches; stormwater pumping stations in low lying areas; rise roadways; gravity wells; raise sea walls; relocation of locks; redevelopment control ordinances).	Multi-hazards (SLR, temperature and precipitation).	"Spatially, the most vulnerable populations are not found in the most physically vulnerable areas at present, but exposure will increase with time. However, the lack of data on emerging diseases makes future projections regarding the health impacts of sea level rise a challenge."	"Models of population migration should be reviewed to determine if sufficient data exists to probabilistically evaluate potential patterns of migration. A second effort may be to develop a probabilistic model that combines sea-level rise. Evaluate current data overseas regarding disease incidence and develop predictive models of growth in Southeast Florida."
39	Freire et al. (2016)	Article	urban/peri-urban	Municipality of Seixal (Portugal)	other	Present an integrated approach to support flood risk	None.	Hybrid (e.g., implement formal system	Flooding	To increase resilience in face of coastal flooding, a set of actions were identified. Some of them are	"An early warning system implemented for the locations with the highest risk of flooding and a set

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						management in transitional systems considering different climate scenarios and levels of the decision-making.		of road signs providing warning of flooded roadways and sidewalks; protect existing wetlands, beaches, and dune systems; forbid the construction of basements in flood-prone areas).		already implemented. Other actions (remodelling of waterfront public spaces) require future action. Few of them address already experienced problems during exceptional storm surges while others should be part of a long-term strategy to minimize impacts of expected SLR	of emergency planning guidelines will assist the municipal civil protection authorities in preparedness and emergency response."
40	Dawson et al. (2018)	Article	Regional/ provincial	Coastal section of the railway line between Dawlish and Teignmouth (UK)	other	To explore the suitability of ROA method to maintain tractability by allowing the application of alternative decision rules.	None.	Hard (e.g., improvement and up-grading of the current defences).	Multi-hazards (storms and high waves).	Despite exiting more information available about the initial infrastructure investment, no adaptation measure meets with the economic efficiency criterion for a straightforward investment decision. This new data does not improve modelling capabilities.	"This innovation (the use of subjective, analyst determined probabilities to simulate alternative attitudes to uncertainty under different future climate scenarios) should be considered for adoption in ROA applications since it effectively captures the range of attitudes towards uncertainty likely to be expressed by stakeholders."
41	Reguero et al. (2018)	Article	Regional/ provincial	US Gulf Coast (USA)	CBA/CEA	To quantify cost and effectiveness of green, grey and policy adaptation measures for current and future risks.	None.	Hybrid (e.g., local levees; sandbags; dikes; home elevation; wetland restoration; oyster reef restoration).	Flooding	"Sandbags are a cheap and temporary measure with the highest benefit to cost ratio (bar height), therefore the most cost-effective. However, they offer low overall risk reduction, compared to other measures. Nature-based measures, particularly marsh and oyster reef restoration, are among the most cost-effective measures (in terms of benefit to cost ratios) and together contribute the most to overall damage reduction (total benefit) from among the combo of cost-effective risk reduction measures in the analysis"	"Assessing the risk reduction potential of restoration projects could support and inform funding allocation from the RESTORE Act into restoration that also would reduce risks to people"
42	Schipper et al. (2021)	Article	Regional/ provincial	North Sea Delta (The Netherlands).	other	To assess the level of sustainability and transitions to coastal resilience solutions and adaptation to climate change.	None.	EBA (e.g., barrier reef and mangrove forests; sedimentation and mangroves).	Flooding	"The potential to develop a more inclusive coastal strategy can be pursued by focusing on the availability and accessibility of data, to enhance climate-resilient and adaptable coastal management as leverage to achieve the relevant SDG targets."	"The SDG-SIS framework is a starting point for discussions on integrated policy since it shows that a set of indicators can be successfully applied to assess flood protection management, rendering it applicable on a global or regional scale for coherent integrated policymaking across sectors to enhance climate-resilient and adaptive management."

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43	Löwe et al. (2018)	Article	district/neighbourhood/street	Elster Creek catchment in Melbourne (Australia)	other	To reduce the computational effort required for quantifying economic flood damage.	None.	Hybrid (e.g., increase of stormwater pipe capacity; flood proofing of buildings; dike construction).	Multi-hazards (flooding and pluvial risk).	SEQUS (stratified sequential scheme) performed better in case A (no adaptation), B (increase of stormwater pipe capacity) and C (flood proofing of buildings)	No recommendations included.
44	Rohat et al. (2021)	Article	urban/peri-urban	Houston, Texas (USA)	other	Assess the effectiveness of adaptation strategies in relation to challenges to implementation.	Citizens and citizens groups	Soft (adaptation strategies related to poverty, social isolation, air conditioning and land use).	Others - extreme heat events.	Most adaptation strategies present high effectiveness but are associated to high challenges to implementation, due to the increasing economic inequalities, decreasing of social policies (social isolation) and low technological development of population.	"Future research could investigate adaptation strategies targeting other potential drivers of individual vulnerability and drivers of institutional adaptive capacity. Further research would also benefit from the use of heat risk models that integrate a larger number of predictive variables upon which the effectiveness of a wider range of adaptation strategies could be assessed"
45	Lane et al. (2017)	Article	Urban/ peri-urban	Charlottetown, Province of Prince Edward Island (Canada)	other	Evaluate coastal community adaptation strategies to environmental change.	None.	Hybrid (e.g., seawalls; grading coastal cliffs; planting or maintaining existing vegetation; elevated houses; zoning plans to restrict permission of coastal constructions; land swapping).	Others – storms.	The SD model results indicate preferred adaptation strategies (and the elimination of dominated adaptation strategies) in the context of the coastal community	"The method promotes the need for a longer-term, strategic planning perspective. The imminent creep of coastal climate change, and the urgency of coastal communities to be better prepared to adapt to the changing coastal environment, require further effort in the strategic analysis of adaptation strategies."
46	Abadie et al. (2017)	Article	District/ neighbourhood/street	Zorrotzaurre, Bilbao (Spain)	other	Assess investments in adaptation and determine whether it is an optimal decision to invest now or delay it.	None.	Hard (opening the pre-existing Deusto canal in Bilbao).	Flooding	The study estimates two risk models: VaR ans ES. Their values can help to define acceptable levels of risk together with policymakers and/or stakeholders. The ROA analysis for the Deusto canal shows that the decision to undertake the investment was well made. The optimal value of current investment on it would have been much higher than the actual cost of the infrastructure.	"Applicability of Risk and ROA methodologies for more complex cases (i.e cases where there exists a wide portfolio of adaptation measures to be evaluated) is a challenge that would be interesting to address in future work."
47	Hérivaux et al. (2018)	Article	Regional/ provincial	Languedoc-Roussillon coastline (France)	other	To estimate the potential benefits of adapting to SLR to help decision makers	None.	Hybrid (beach nourishment; road relocation;	Multi-hazards (coastal erosion and flooding).	SLR effects emerge in 2040 onwards. At the 2100 horizon, major impacts are expected to come from housing losses (80% of	"A stepwise knowledge-sharing process should be set up before the integration of ecosystem services in the policy decision-making framework

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						discussing the possible consequences of the different adaptation options.		relocate population, housing and economic activities).		the total) and losses of beaches and dunes (15% of the total). This underlines the need to take some early decisions and the need to "conduct research on new technologies and economic instruments is immediate." "Our results underline the importance of incorporating coastal ecosystems into the assessment of adaptation scenarios. (...) classic cost-benefit analyses used to rank alternative adaptation options may underestimate the benefits associated to adaptation in some situations because, in general, they do not account for ecosystem services."	can be envisaged. Further research should also be conducted to improve our understanding of the impact of SLR on coastal ecosystems and to develop ecosystem-based adaptation strategies. An analysis of the feasibility and acceptability of the different options for the local population and decision-makers is also essential"
48	Berte and Panagopoulos (2014)	Article	urban/peri-urban	Faro (Portugal)	other	To provide information and tools for local administration to strengthen the green areas and mitigate urban threats.	Stakeholders involved, but not specified.	EBA (permeable soils; shadow to streets, sidewalks and buildings through trees plantation and green walls; supporting proper planning that considers impacts on waterways).	Multi-hazards (heatwaves, flooding, and water scarcity/drought).	"The services provided by urban green infrastructure can help to mitigate flooding, heatwaves and water scarcity in cities, in particular, through their regulation function." The results of the SWOT analysis help decision-makers to define the site-location adaptation strategies	Implement SWOT analysis results for applying an ecosystem services, maintenance, and enhancement approach in the city of Faro
49	Woodruff et al. (2018)	Article	Regional/ provincial	North Carolina's Outer Banks barrier islands; Dorchester County, Maryland (USA)	other	To test vulnerability trajectories associated with investment strategies in coastal infrastructure protection.	None.	Hybrid (e.g., seawalls; green infrastructure for shoreline stabilization; beach and dune nourishment; elevation; post-disaster relocation).	SLR	Results reveal the positive relation between protection and economic value. If higher investments in protective infrastructure are not incentivize in the near future, many socially disadvantaged Americans living in coastal areas could be highly affected by SLR.	"More investigation needs to explore the precise mechanisms by which SLR risk affects insurance rates, immigration and emigration patterns, financial investments in infrastructure, and EA in coastal regions. Furthermore, additional steps could be taken to test our model more thoroughly against empirical evidence from communities that have already experienced substantial investments in adaptation infrastructure due to SLR-associated flooding"
50	Manocha and Babovic (2018)	Article	district/neighbourhood/street	Kent Ridge (Singapore)	other	To identify a preferred pathway(s) that will be followed under certain climate change forecast.	None.	Hybrid (expansion of drainage canals; implementation of green	Flooding	When measuring with NPV, adaptation measures reveal similar results in terms of two defined approaches (BTT and BU). The pathways developed for the sustainable grey land use	"Given the nature of the problem (NPV or ROA), it may not appropriate to use a single criterion to justify the choice of the plan used to combat uncertainty. This notion can be addressed further in future studies by

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								roofs; and implementation of porous pavements).		consistently maximize the value of the selection criterion across the entire set of climate scenarios.	exploring the use of multiple objective genetic optimizations in designing and subselecting adaptation pathways."
51	Ćulibrk et al. (2021)	Article	Regional/ provincial	Beach of Kamari (Greece)	other	To assess the viability of the selected protection measures, and their impact on the beach and the society.	Citizens and citizens groups.	Hybrid (beach protection by breakwaters and sand replenishment)	Multi-hazards (coastal erosion and SLR).	The proposed optimal solution is the construction of breakwaters in combination with sediment replacement. It is found to be the only viable solution that ensures stability in the region and does not pose a risk either to the tourism industry or to the properties of the inhabitant.	No recommendations included.

Source: Own elaboration.