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Urban Planning for Climate Change: A Toolkit of Actions for an Integrated Strategy of Adaptation to Heavy Rains, River Floods, and Sea Level Rise

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Abstract: Cities and urban systems are the places most responsible for climate change, but at the same time they are the places where its effects are felt the most. A state-of-the-art analysis showed that Ecological–Environmental, Settlement, and Infrastructure and Service Systems are the components of cities most exposed to risk phenomena. Therefore, it is important to identify site-specific actions aimed at enhancing ecosystem services and building hierarchical ecological networks (green and blue infrastructures), according to an *Ecosystem-based Approach* (EbA). In this regard, the contribution presents the results of a research work on the theme of multi-risks connected to climate change, referring to heavy rains and river flood phenomena and sea level rise and proposes a systematisation of international best practices in the field of the *Ecosystem-based Approach* (EbA). Each best practice analysed is traced back to the three urban resilience macro-strategies of "defence", "adaptation", and "relocation/de-anthropisation", already conceptualised by the authors during their joint research activity. The aim is to outline a synthetic toolkit of site-specific design actions, exportable to other contexts, intended as a tool to support the innovation of urban planning tools at the local level.

Keywords: urban regeneration; urban resilience; climate change; climate-proof planning; ecosystem-based approach; local urban plan; nature-based solutions; resilient strategies; site-specific actions; urban toolkit

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1. Introduction

In recent decades, the need to identify new references for a sustainable transformation of the territories affected by risks and degenerative processes connected to climate change [1–5] has stimulated the scientific and disciplinary debate on the key role of urban and territorial planning. This aspect also highlights the urgency of updating the skills of urban planners and spatial governance tools concerning the elaboration of possible regeneration and climate change resilience strategies.

As advocated by the document *Guidelines for Ecosystem-based Approaches to Climate Change Adaptation and Disaster Risk Reduction* [6], these strategies imply an overcoming of the traditionally sectorial approach to these themes, in favour of an integrated approach to urban complexity [7] ascribable to the *Ecosystem Based Approach* (EbA) [8]. In this sense, it is important to emphasise the need to define the elements of a knowledge process aimed at a circumscribing the areas of the territory most vulnerable to the effects of climate change, with specific reference to the possible impacts on the Ecological–Environmental, Settlement, Infrastructural and Services System, and on the System of Socioeconomic relations [9].

In this sense, the authors in their joint research activity highlight the need to integrate and update urban planning tools at the local level (local urban plan) in the light of current knowledge on the effects of climate change on the territory.

The research activity carried out so far has led to the definition of two parallel dimensions of the reforming action of the urban planning discipline: on the one hand, a strategic dimension aimed at defining ecologically oriented urban regeneration strategies (in relation to this aspect, in Section 2.1 " *State-of-the-art: "defence", "adaptation" and*

"relocation/de-anthropisation" as strategic response to the effects of climate change on the territory", reference is made to the conceptualisation of three macro-strategies of ecologically oriented urban regeneration, which the authors have previously conceptualised].), and on the other, a regulatory dimension, characterised by a dual purpose:

- Update the descriptive apparatus of the local urban plan highlighting and relating the areas at risk with the plan forecasts on those same areas;
- Integrate the prescriptive apparatus of the local urban plan with climate-proof and site-specific adaptation actions (a first result, preparatory to this purpose, is expressed in this contribution with the conceptualisation of the toolkit of adaptation actions to heavy rains and river flood phenomena, and sea level rise, presented in Section 4).

The authors believe that this disciplinary updating process will be able to introduce and accompany the construction of integrated strategies of climate-proof regeneration, in line with the goals of the *European Strategy on adaptation to climate change* [10]. The main purpose of this process is to combine the emergency dimension with a proactive perspective of design and transformation of the territory in a sustainable key, within which all the elements of the built environment find a new balance with each other and with natural elements to favour efficiency and high-performance levels [11].

To make this perspective feasible, spatial government bodies should put in place strategies, plans, and programs capable of addressing:

- An analysis of the impacts and vulnerabilities of territories exposed to risk;
- The adoption of defence and risk mitigation measures with a short and medium-term time horizon;
- The adoption of adaptation strategies with a long-term time horizon;
- The monitoring of actions over time.

The report *Cities on the route to 2030. Building a zero-emissions, resilient planet for all* [12] highlights some statistics on the measures implemented globally by cities in response to climate change, which show that:

- 93% of cities are facing significant risks due to climate change;
- Only 59% of cities have conducted a climate risk vulnerability assessment to date;
- 43% of cities, representing a projected population of over 400 million people by 2030, still do not have any adaptation plan to address climate risks;
- 60% of cities have water safety problems;
- Only 46% of cities include water security in their vulnerability assessments even though water is one of the cornerstones of mitigation and adaptation actions.

However, in this framework it emerges how local public administrations are working on processes of integration and the innovation of urban planning tools and instruments at the local level in response to climate change (in Europe, 66% of cities declare having a climate change action plan) moving from the mere defensive approach, adopted so far, to strategies and actions inspired by Nature-based Solutions (NbS) [13,14]. This trend is triggering virtuous processes of environmental regeneration, based on compensation and the ecological–environmental potential of the solutions adopted, providing integrated responses both to the need for anthropic development and the preservation of natural capital, combining morphological, cultural, and social redevelopment with ecological and landscape enhancement actions [15].

Therefore, starting from these experiences it is possible to outline new theoretical–methodological references for an innovative planning system that are able to support urban regeneration strategies according to the specificities of territorial contexts. Beyond that, through updated urban planning tools and instruments, it is also possible to pursue actions that have significant effects on the mitigation and adaptation to the effects of climate change [16].

The numerous project experiences analysed in the research can be traced back to the ecosystem-based approach and represent a reference model for urban regeneration actions in an ecological key. However, in the literature the results of these best practices are always

described in general terms concerning the improvement achieved in response to climate change (from a technological and economic performance and efficiency point of view). The effects that each action has on the physical components, which constitute different territorial systems (Ecological–Environmental, Settlement, Infrastructures, and Services) are rarely analysed in detail, which does not fully allow these models to be exportable to other contexts. This limitation also constitutes a further difficulty in the implementation of such climate-proof actions within the regulatory apparatus of urban planning instruments [17].

In relation to what has been expressed so far, the purpose of this contribution is to conceptualise a toolkit of adaptation actions to some specific effects of climate change on the territory and to set the stage for an update of the prescriptive apparatus of the local urban plan.

So, the research question at the base of this study concerns the possibility of proceeding to an analytical examination of some best practices highlighting the site-specific actions of which they are composed and dividing them into individual systems and territorial components in order to identify a toolkit of climate-proof actions that can be exported and replicated in other territorial contexts. This type of analysis ensures on the one hand the understanding of the integrated territorial strategy in its entirety and, on the other, it makes local differences evident, thus guaranteeing the exportability of the single solution to similar territorial contexts.

An in-depth analysis of the territorial effects of site-specific actions is an important issue since its understanding will facilitate the correct application of general urban policies towards areas at risk [18].

The authors believe that making the individual actions—concerning territorial systems—evident and comparable makes it possible to improve the integrated territorial strategy that each public administration will have to implement in the future. Taking climate-proof action effects into consideration for the development of the territory also means evaluating positive and negative effects and the future impacts that need to be analysed and discussed in terms of benefits for the area. This aspect may give a sense of urgency to some actions, which then require particular attention and faster decisions and actions [19].

The Impacts of Climate Change on the Systemic Components of the City

Cities and urban systems are the places most responsible for climate change [20], but at the same time they are the places where its effects are felt the most. Cities are responsible for 70% of CO2 emissions and the transport sector accounts for 30% of the total, with a growth of around 2% to 3% per year [21]. Rising urban temperatures and critical hydraulic problems are the two most noticeable effects. Large and sealed areas, lack of vegetation, and waste production lead to increased heat absorption avoiding proper water runoff, making these areas more vulnerable to heat waves, drought peaks, and heavy rainfall, while urban settlements along the coast are threatened by rising sea levels.

The effects of climate change in each city vary not only according to the type of impact caused by a specific risk phenomenon, but also according to the city's level of urban development, its ability to react to impacts, and the physical nature and the vulnerability of the territorial component affected by the specific phenomenon. As previously mentioned, taking into consideration all these aspects, the authors have developed a replicable methodology for the definition of risk maps to the rising sea level phenomenon at the local scale, thanks to which it was possible to relate the areas at risk of flooding due to sea level rise with the systemic components of "Ecological–Environmental", "Settlement", and "Infrastructure and Services" [22]. This result paved the way for an update of the descriptive apparatus of the local urban plan in the light of current knowledge about the effects of climate change on the territory.

Indeed, as highlighted by the *report Cities on the route to 2030. Building a zero-emissions, resilient planet for all, in the table Cities services and assets most affected by climate change* [12], Ecological–Environmental, Settlement (with reference to the residential function), and

Infrastructure and Services Systems are listed among the components most affected by climate change, in third, fourth and fifth place, respectively, while water supply and public health appear in first and second place.

Therefore, the process of integration and innovation of planning tools will have to envisage site-specific actions within a more general strategy of adaptation to climate change. Moreover, these actions will have to be differentiated in relation to a systemic reading of the territorial components affected by the impacts. In addition to this, it will also be opportune to highlight in which of the three macro-strategies of "defence", "adaptation", and "relocation/de-anthropisation", already conceptualised by the authors during their joint research activity, the specific action falls [11].

The Settlement System and the Infrastructure and Services System correspond to the urbanised area of territories, which includes the main settled functions, the infrastructure and transport network. The largest percentage of energy consumption comes from these areas, but at the same time, they represent the main testing ground to experiment with urban resilience tactics and adaptation strategies capable of responding to the challenges of climate change.

Requalification interventions on the existing building stock through energy efficiency actions will trigger a paradigm shift that promotes an integrated urban design capable of ensuring benefits such as improving public health and urban welfare for the cultural, economic, and social growth of communities. This will be possible thanks to the construction of an urban environment with a high climate adaptation performance, which includes the mitigation of the "heat island" effect through the reduction in energy consumption for cooling and heating in buildings, associated with more efficient and low carbon transport strategies and multimodal networks [4,23].

At the same time, the enhancement of ecosystem services and the realisation of hierarchical ecological networks (green and blue infrastructures) will also lead to positive effects on the Ecological–Environmental System and the components of natural capital; this will be possible through actions aimed at protecting and enhancing biodiversity, reducing land consumption and soil sealing, encouraging environmental regeneration and soil renaturation through sustainable stormwater management, and promoting water saving and sustainable urban drainage [24].

In the more general scenario of the ecological transition advocated by community programs and policies such as the *Millennium Ecosystem Assessment* (2005) [25], the *Sustainable Development Goals* [4], the *European Green Deal* and the *New European Bauhaus* (2021), as well as in the Italian national context with the *PNRR 2021*, these perspectives for action represent the founding goals of urban regeneration programs and adaptation strategies currently being tested in the Italian and European national context.

In this framework and in continuity with the research activity carried out jointly by the authors in the field of what is defined as *climate-proof planning* [22,26,27], the contribution shows the results of a research work (Research of Sapienza University of Rome (Scientific Coordinator Prof. C. Mariano). " *Strategies of urban regeneration for climate proof territories. Tools and methods for vulnerability assessment and for the identification of resilience tactics for coastal urban areas subject to sea level rise"*) on the theme of multi-risk connected to climate change, referring to heavy rains and river flood phenomena and sea level rise. The research proposes a systematisation of international best practices, characterised by an approach that can be traced back to the *Ecosystem-based Approach* (EbA), which is useful to define a synthetic toolkit of site-specific planning actions, exportable to other contexts, intended as a support tool for the innovation of urban planning tools and instruments at local level.

Therefore, the innovative character of the current research lies in the conceptualisation of methodological, experimental, and operational references that allow policymakers and bodies in charge of the territorial government to define specific responses at the local scale concerning the territorial effects caused by climate change [28]. In this way, it will be possible to assume within the policies and planning tools new climate-proof project

categories that respond to specific instances linked to a specific territory and allow the localised choice of "defence", "adaptation", and "relocation/de-anthropisation" strategies.

In particular, the analysis and critical examination of best practices was based on the study of dossiers and reports by public administrations and published on institutional websites, articles, and scientific proceedings, interviews, and discussion meetings with representatives of the municipalities and projects concerned.

2. Materials

2.1. State-of-the-Art: "Defence", "Adaptation", and "Relocation/de-Anthropisation" as Strategic Responses to the Effects of Climate Change on the Territory

Based on what has been expressed so far, the research activity of the authors focused on the definition of theoretical–methodological references aimed at classifying site-specific actions of urban adaptation to the impacts of climate change on the territory sufficiently general to be exportable to other contexts. This could help in updating the prescriptive documents of the local plan in line with the principles of what is called *climate-proof planning*. To this end, it was necessary to adopt a strict "reading" method of the best practices to break down the projects into their intrinsic characteristics. As mentioned in paragraph 1.1, the authors already provided a categorisation of best practices in their work *Defence, adaptation, and relocation/de-anthropisation. Three strategies for urban planning of coastal areas at risk of flooding* (2018), identifying three main approaches of urban adaptation interventions to the effects of climate change: "defence", "adaptation", and "relocation/de-anthropisation" [11].

Therefore, the research presented in this contribution represents the state-of-advancement, on a theoretical and methodological level, of the macro-categorisation. The aim was to integrate the previous conceptualisation with a systemic reading of the components of the territory affected by the risk phenomenon in order to make urban adaptation solutions exportable and integrable with planning tools.

Before entering the merits of the proposed advancement, it is necessary to briefly outline the preliminary work of conceptualisation and the definitions of the three macro-strategies from which this research originates. The conceptualisation was defined by considering the impact of coastal flooding caused by sea level rise on several coastal cities in an international context, but as shown in Section 3.1, the theoretical approach is also exportable to other effects (for this contribution the methodology was tested not only to best practices related to the sea level rise phenomenon but also to the ones concerning heavy rains and river floods).

The macro-category conceptualised ("defence", "adaptation", and "relocation/de-anthropisation") comes from an inductive analysis of strategic plans, projects on the urban scale, and scientific theories and debates at the international level concerning the need to:

1. Defend the territory from the effects of sea level rise on coastal cities through engineering works aimed at "securing" areas exposed to potential flood risks on the base of sea level rise projections to 2100;
2. Increase the resilience of the urban structure to flooding phenomena through strategies capable of adapting the urban form to the environmental context through actions of reconfiguration of morphological components, considering flexibility and diversity as priority elements [29]. Basically, actions that take the form of real opportunities to implement an ecological transition of territories damaged by climate change;
3. Relocate activities and settlements present in areas exposed to greater risk to other geomorphologically safer, even if the investment cost for mitigation is considered unsustainable, thus giving priority to the survival of the area itself [30].

2.2. State-of-Advancement: Integration of Macro-Strategies with the Systemic Component of the Territory for a Critical Reading of Best Practices

As already pointed out, the components most affected by climate change are water supply and public health [12], underlining the symbiotic relationship between quality of

life and quality of the urban environment [31,32], an issue that is among the most topical and central to the current literature and scientific disciplinary debate.

However, it is also true that these two components, linked to the human dimension, create transversal connections with those of physical–spatial definition and qualitative characterisation of the territory, that is the components that fall under the Ecological–Environmental, Settlement, Infrastructure, and Service Systems, which the aforementioned Report [12] places third, fourth, and fifth in the ranking of components affected by climate change risk.

Therefore, from a methodological disciplinary point of view, it is necessary to recognise these structuring systems to acquire a profound knowledge of the urban context analysed [33]. This preliminary categorisation and synthesis on the best practices allow us to understand how the effects of site-specific design actions, which flow into the more general urban regeneration macro-strategies of "defence", "adaptation", "relocation/de-anthropisation", affect the systemic components of the territory, so it will be possible, as a future development, to also introduce new punctual indicators (related to each system) for the climate-proof innovation of the planning instruments.

Based on what has been expressed so far, the authors define these systems as:

1. Ecological–Environmental system;
2. Settlement system;
3. Infrastructure and Services system.

The first one relates to the environmental components with those concerning the ecological and landscape aspects of the territory, as understood by the European Landscape Convention (2000), that are all those aspects of perceptive and identity character that describe the landscape as «an area, as perceived by people, whose character is the result of the action and interaction of natural and/or human factors» [34]; the second is aimed at understanding the relationships between the morphological ordering elements of the urban space (roads and open spaces with a defining role for the urban structure, fabric matrix, building types, etc.) and the prevailing functions (residential, productive, tourist, commercial, etc.); the third offers a categorisation of the infrastructures understood as mobility infrastructures and territorial endowments and is aimed at describing the level of accessibility of the area under analysis (through the categorisation of roads, rail network, public transport, etc.) and in terms of accessibility to public services, a topic strongly connected to the aforementioned issue of urban welfare [35].

3. Method

The methodology proposed for the systematisation of best practices and the subsequent synthesis of exportable site-specific adaptation actions is divided into three main phases:

- Phase 1 | Elaboration of a matrix that relates each selected best practice (concerning a specific phenomenon) with the prevailing macro-strategy ("defence", "adaptation", and "relocation/de-anthropisation") and with the system most involved in the adaptation intervention ("Ecological –Environmental", "Settlement", and "Infrastructure and Services");
- Phase 2 | Description and critical analysis of strategies, goals, and actions;
- Phase 3 | Presentation of the results: summary of the specific actions in a toolkit.

3.1. Phase 1. Selection of Best Practices

The first phase of the research was dedicated to the selection of three best practices for each of the phenomena analysed, that were heavy rains and river floods, and sea level rise (indicated as "Challenge" in the matrix in Table 1) that met the criteria of the *Ecosystem-based Approach* (EbA) and which fell in the field of *Nature-based Solutions* (NbS).

Table 1. Matrix for the selection of best practices.

Challenge		Best Practices	Macro-Strategies	Prevailing System
Heavy rains and river flood	1.	*Lower Danube Green corridor*	De-anthropisation	Ecological –Environmental System
	2.	*Waterplain in Benthemplein*	Defence and adaptation	Settlement System
	3.	*Storkeengen (Stork Meadow)*	Defence, adaptation and de-anthropisation.	Infrastructure and Services System
Sea level rise	4.	*Coastal Planning in Ugento*	Defence and adaptation	Ecological–Environmental System
	5.	*Hamburg floading city*	Defence and adaptation	Settlement System
	6.	*Hunts Point Lifelines*	Defence and adaptation	Infrastructure and Services System

A matrix was then developed to highlight the prevailing strategy of each best practice among "defence", "adaptation", and "relocation/de-anthropisation" (indicated as "Macro-strategies" in the matrix in Table 1) and the system most involved in the adaptation intervention among Ecological–Environmental, Settlement or Infrastructures and Services (indicated as "Prevailing system" in the matrix in Table 1).

Best practices have been numbered to facilitate the recall within the toolkits presented in Section 4.

The selection of the case studies derived from a careful study of reports and documents, including *Nature-based solutions in Europe: Policy, knowledge and practices for climate change adaptation and disaster risk reduction* [36], *the EU Strategy on Green Infrastructure* [37], the New EU Adaptation Strategy [10], as well as digital platforms funded by the European Union, within the Horizon Europe 2020 program, which proposes a real "inventories" of NbS, such as Oppla [38], Naturvation [39], Thinknature [40], Natural Water Retention Measures [41] e Panorama Eba [42].

In this regard, other interesting best practices were included in the toolkit for synthesis needs because the results of the contribution had the sole purpose of illustrating the methodology of analysis, comparison, and synthesis of the best practice, and its possible fields of application, which are not able to represent exhaustively the whole panorama of NbS.

Among these, the following are noteworthy:

1. *Billion Oyster Project* (New York City, USA), another winning project of the *Rebuild by Design* competition. The project aims to defend the coast from sea level rise and its actions mainly involve the Ecological–Environmental System [43];
2. *The Climate District in Østerbro* (Copenhagen, DK). The project aims to respond to the frequent floods that affect the city every year and its actions directly involve the Settlement System in its entirety [44];
3. *Enghaveparken—Climate Park* (Copenhagen, DK). The project aims to respond to the frequent floods that affect the city every year and its actions involve more directly Infrastructure and Services System [45];

3.2. Phase 2. Critical Description and Comparative Analysis of the Best Practices Selected: Strategies, Goals, and Actions

The second phase was about a critical description of the best practices, aimed at contextualizing the project also concerning the "challenge" to which it was required to give answers, and then at highlighting the prevailing strategy, goals, and specific actions through a brief description of the interventions.

Lower Danube Green corridor

The project was born in 2000 from a convergence of intentions between the governments of Bulgaria, Romania, Ukraine, and Moldova, and the *WWF Living Planet Programme* to establish a green corridor along the entire length of the Lower Danube River.

The *Lower Danube Green Corridor Agreement* came from the need to protect and manage the Lower Danube in a sustainable way. Indeed, the interventions are aimed at protecting and restoring wetlands along the river and reconnecting the river to its natural flooding

areas, reducing the risks of major flooding in areas with human settlements, and offering benefits both for local economies and for the ecosystems along the river.

The project is characterised by an integrated, adaptive approach aimed at the de-anthropisation of the area, with the goals of restoring the floodplains (Figure 1) and preserving currently unprotected areas to foster biodiversity; it pursues these goals through the removal of existing embankments to encourage natural flooding, the removal of weed species, and the planting of native trees to encourage the natural regeneration of the forest [46].

Figure 1. Aerial view of the Danube. Original picture by Alexander Ivanov for WWF, graphically modified for editorial purposes.

Waterplain in Benthemplein

The project is part of the *Rotterdam Climate Initiative (RCI) 2007–2025* (born in 2007 from the collaboration between the city of Rotterdam, the Port of Rotterdam, and associations of local entrepreneurs to reduce CO2 emissions by 2025 and to achieve the complete protection of the city from the effects of climate change.) and was designed and completed in the city of Rotterdam (NL) by the Dutch architectural firm *De Urbanisten* between 2011 and 2013. The project aims to manage the heavy rains that often occur in the city of Rotterdam by flooding large parts of the city every year (this is the main goal of the project). Even before the project of the water square, underground tanks were set up throughout the city of Rotterdam for the collection and containment of rainwater. However, these structures were expensive, so the municipal administration decided to support a strategy that provided a new concept of water accumulation systems (on the urban surface) to also contribute to the environmental quality of the urban space, as well as to strengthen the identity of the neighborhood.

The project is characterised by an integrated, defensive, and adaptive approach, and its main goal is achieved thanks to the construction of rainwater catchment basins that in favourable weather conditions can be used as recreational spaces (Figure 2), the integration of gutters that convey water from building roofs into the basins, and the construction of stormwater drainage channels that in favourable weather conditions can be used as recreational spaces, such as skateboard tracks [47].

Figure 2. Aerial view *Waterplain in Benthemplein*. Original picture by Ossip van Duivenbode for De Urbanisten, graphically modified for editorial purposes.

Storkeengen (Stork Meadow)

The project was designed by the Danish architecture firm *C.F. Møller Architects* and realised in Vorup, near Randers (DK) between 2017 and 2022.

It is an adaptation project which aims to solve the current and future challenges of the city (especially the increase in rainwater levels) by converting the adjacent natural area of Storkeengen (Stork Meadow), into a public natural park. Through the integration of climate resilience strategies, the new park also brings the natural delta of Gudenå (the longest river in Denmark) closer to the center of Randers and its inhabitants. The project is characterised by the integration of all three approaches, is defensive and adaptive, and aimed at de-anthropisation, its main goals are to protect the floodplain to avoid overloading of the sewage system and encourage the enjoyment of the landscape by the population also for educational purposes; it pursues these goals through the creation of an urban park characterized by wetlands, integration of gutters that convey water from the roofs of the buildings into the basins, and the construction of elevated walkways that cross the wetlands (Figure 3) [48].

Figure 3. Raised walkways that cross the wetlands. Original picture by C.F. Møller Architects, graphically modified for editorial purposes.

Coastal Planning in Ugento

The project is part of the *Interreg V-A Greece-Italy Cooperation Programme 2014–2020*, implemented between 2018 and 2020 in Ugento (IT) to mitigate the effects of coastal erosion and preserve the landscape of one of the most appreciated and naturalistically relevant

stretches of the Apulian coast (Italy). To this end, the project includes bioengineering interventions, among which nourishment, restoration of the dune strips, and the dredging of the fishing port are included, but also nature-based solutions, on which the interest of the authors is focused.

The project is characterised by an integrated, defensive, and adaptive approach. Its primary goal is to mitigate the effects of coastal erosion; the nature-based solution to achieve this goal is the remodelling of the dunes through the circular integration of natural waste collected along the shoreline, that is *Poseidonia oceanica* leaves washed up in the mouths of the drainage channels (Figure 4) [49].

Figure 4. Posidonia Oceanica leaves which obstruct the drains. Original picture by LeccePrima graphically modified for editorial purposes.

Hamburg floading city

The project is part of the design of the new *Hafen City* district in Hamburg, designed by *Kees Christiansee with the ASTOC team*. Work started in 2003 and the completion of the works is scheduled for 2025. The urban area where the project stands is surrounded by the river and canals. The general urban plan of the city emphasises the need to preserve the unique character of the site and the maritime atmosphere, but at the same time consider the risk of flooding from the Elbe River, induced by the rise in sea level.

The project is characterised by an integrated, defensive, and adaptive approach, and its primary goal is to protect the built-up area near the coast; it pursues this objective through the construction of artificial hills to raise buildings approximately 8/8.5 m above sea level (Figure 5) [50].

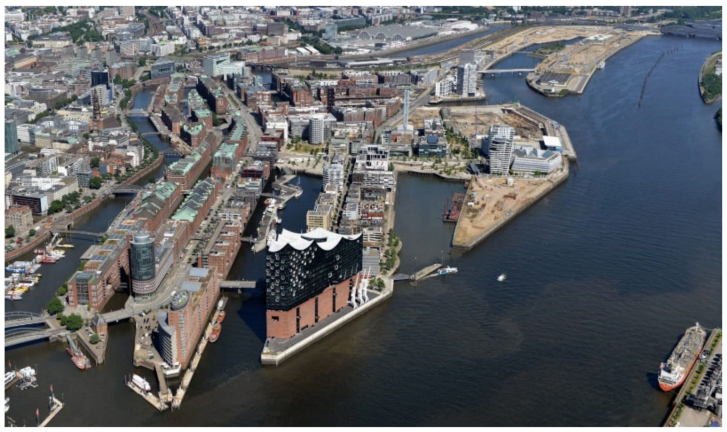

Figure 5. The artificial dunes of Hamburg's floying city. Original picture by Kcap, graphically modified for editorial purposes.

Hunts Point Lifelines

This was one of the winning projects of the *Rebuild by Design* competition (*Rebuild by Design* is a competition launched in 2014 following Hurricane Sandy (in 2012 in the USA) to asks some of the world's most talented design professionals to envision solutions that would increase resilience across the Sandy-affected region.), launched in 2014 in the aftermath of Hurricane *Sandy*. The project site is in Hunts Point, Bronx, NYC and is currently under construction. Although Hurricane Sandy has spared much of Hunts Point, the area is still vulnerable to flooding. Climate change and rising sea levels increase the threats for the inhabitants who are already challenged by poverty, isolation, and environmental degradation. The project is characterised by an integrated, defensive, and adaptive approach, and its primary goal is to protect the urban settlement, infrastructures, and coastal vehicular mobility from sea level rise, but at the same time ensure green coastal mobility; it pursues this goal through the construction of a bicycle-pedestrian road infrastructure elevated above sea level with the additional function of protecting the urban settlement and the coastal vehicular road (Figure 6) [51].

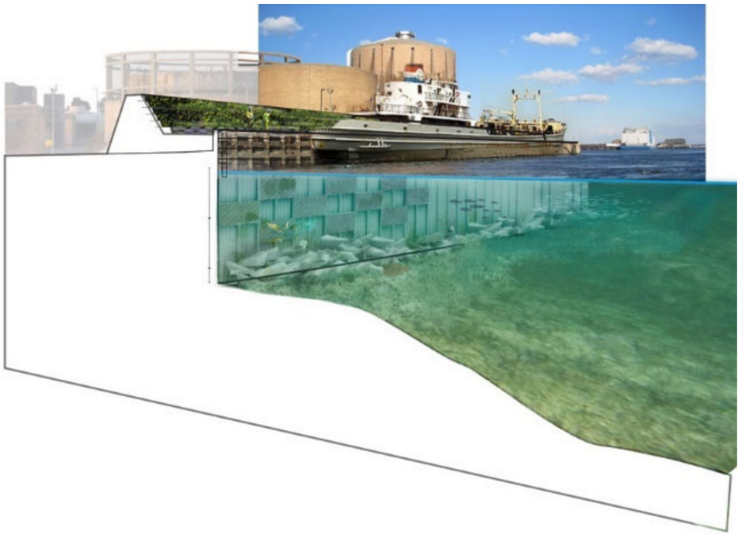

Figure 6. The infrastructure to protect the building against rising sea levels. Original picture by Rebuild by Design, graphically modified for editorial purposes.

4. Phase 3. Results: Toolkit of Integrated Adaptation Strategies and Actions

Based on the best practices compared in Table 1, this paragraph intends to outline a synthetic and summarising toolkit that highlights the relationship between *challenge*, *goals*, and *action*, in the form of a handbook of site-specific project actions referring to the prevailing physical–territorial systems (Ecological–Environmental, Settlement, Infrastructure and Services) that are exportable and replicable in other contexts.

This elaboration assumes some methodological references that have already been developed such as the drafting of *Guidelines for Climate Adaptation Plans*—the case of Padova [52] and Mantova [53] in the Italian context—and some Strategic Plans in the international context, such as *Vejle Resilient* [54], which catalogue some site-specific actions considering:

(a) The time horizon of implementation (short, medium, long);
(b) The scope of application (physical, organisational, economic);
(c) The level of effectiveness (payback time).

In this framework, it is evident that each of the site-specific actions illustrated in the section "Materials and Methods", although having a prevalent approach (some more oriented to defence, others to adaptation, and still others to the relocation of functions and/or people, promoting de-anthropisation actions) are characterised by an integrated approach, where defence, adaptation, and relocation/de-anthropisation actions complement each

other in favour of a resilient and integrated approach to the effects of climate change, which determines more direct effects in one system rather than another.

In this sense, toolkits 1 and 2 (Tables 2 and 3) propose a synthesis and systematisation of the actions described in the Section 3.

Table 2. Toolkit on the heavy rains and river flood phenomena.

Challenge	System	NbS	Target	Actions	Macro-Strategies		
					a	b	c
Heavy rains and river flood	Ecological-environmental	1	Restoring floodplains	Embankment removal			●
			Preserving currently unprotected areas and fostering biodiversity	Removal of weed species		●	●
				Planting native trees		●	●
	Settlement	2	Favouring rainwater storage	Creation of catch basins in the public space	●	●	
			Avoid overloading the sewage system	Construction of integrated gutters to facilitate the connection between building roofs and rainwater catchment basins	●	●	
			Avoiding surface runoff	Construction of stormwater drains	●	●	
	Infrastructure and Services	3	Protection of the floodplain	Reliance on an urban park characterised by the presence of wetlands		●	●
			Avoid overloading the sewage system	Construction of integrated gutters to facilitate the connection between building roofs and rainwater catchment basins	●	●	
			Promoting the enjoyment of the landscape by the population also for educational purposes	Construction of elevated walkways	●	●	●

Table 3. Sea level rise toolkit.

Challenge	System	NbS	Target	Actions	Macro-Strategies		
					a	b	c
Sea level rise	Ecological-environmental	4	Mitigating the effects of coastal erosion	Remodelling dunes through the circular integration of natural waste	●	●	
	Settlement	5	Protecting the built-up area near the coast	Construction of artificial hills to raise buildings	●	●	
	Infrastructure and Services	6	Ensuring green coastal mobility	Construction of suspended cycling and pedestrian infrastructure		●	●

The proposed systematisation leads each specific action (*actions*) back to the more general objectives (*targets*) and groups them in relation to their effects on the prevailing physical–territorial systems: Ecological–Environmental, Settlement, Infrastructure and Services specifying if the action falls more directly into a defensive approach (indicated in the Tables 2 and 3 with the letter "a"), adaptive (indicated in the Tables 2 and 3 with the letter "b"), delocalising/de-anthropisation oriented (indicated in the Tables 2 and 3 with the letter "c"). The purpose of this synthesis operation is to obtain a matrix of solutions sufficiently general to be exportable to other contexts as support for policymakers.

5. Conclusions and Future Developments

The *European Environment Agency* (EEA), in its recent report *Nature-based solutions in Europe: Policy, knowledge and practice for climate change adaptation and disaster risk reduction* of 2021, proposes an "Umbrella concept", that is a grouping of the different types of NbS by macro-themes: biodiversity, forests, land use and forestry, water, agriculture, and climate change adaptation and risk reduction, associating with these the main international and EU directives that regulate and discipline their implementation: *The EU Biodiversity strategy for 2030* [55], one of the core elements of the *European Green Deal* [56], *The EU Strategy on Green Infrastructure* [37], *The New EU Forest Strategy for 2030* [57], *The LULUCF (Land Use, Land Use Change and Forestry) regulation, water and floods directives* [58], *The Common Agricultural Policy* [59], *The EU Adaptation Strategy* [10], *The Action Plan on the Sendai Framework for Disaster Risk Reduction 2015–2030* [60].

Equally, as mentioned in Section 3.1 there are several platforms funded by the European Community, within the *Horizon Europe 2020* programme, which propose real "inventories" of NbS, each using different selection criteria:

- The *OPPLA* platform aims to share practical knowledge on natural capital, ecosystem services, and nature-based solutions, offering a wide range of case studies, products and tools [38];
- The *NATURVATION* project produces an atlas of a thousand examples of nature-based solutions from 100 European cities that contribute to adapting the urban system to climate change [39];
- The *ThinkNature* platform is a real hub of nature-based solutions, which also offers interactive experiences to allow the user to experience the application of the solutions on a climate-proof "ideal city" [40];
- The *Natural Water Retention Measures* platform collects information on green infrastructure applied to the water sector, with an extensive catalogue of actions and case studies [41];
- The *Panorama EbA* platform facilitates the sharing of case studies and examples of EbA from different regions and ecosystems around the world and is organised as a real search engine, through which everybody can search for the desired project solutions [42].

In this sense, aware that the proposed toolkits could be implemented with other relevant nature-based adaptation actions, the authors' intent was to provide a guide in the choice of site-specific solutions related to the heavy rains and river flood and sea level rise phenomena, starting from a systemic macro-categorisation referring to the physical–territorial dimension (Ecological–Environmental System, Settlement System and Infrastructure and Services System) in order to allow a more direct match between the characteristics of the context under analysis and the site-specific design actions, thus providing an exportable and replicable model in different contexts, also applicable to different risk phenomena linked to climate change.

This guide will enable public administrations to modify their urban planning instruments concerning possible location forecasts of functions not compatible with the risks linked to the expected territorial impacts due to climate phenomena. In this sense, it will be possible to elaborate integrated adaptation strategies for these territories by implementing the prescriptive contents of planning tools through site-specific project actions referring to single territorial components.

Thus, concerning the thematic contextualisation of the research, presented in the introduction, the toolkits presented in Section 4 represent a first result, preparatory to the integration of the prescriptive apparatus of the local urban plan, and are contextualised in a broader research work that the authors are conducting, in collaboration with ENEA's Climate Modelling Laboratory, on the coastal areas of the Lazio Region (Italy), with reference to heavy rains and river flood and sea level rise phenomena.

The future goal of this research is to test this toolkit methodology on the area of Isola Sacra, on the Lazio coast, in the municipality of Fiumicino (Italy), which presents degenerative processes connected to the phenomena highlighted, and for which an integrated adaptation strategy must be identified.

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