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Nature-based Solutions for climate adaptation and mitigation in Deltas and coastal areas.

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Coastal areas, especially deltas, are some of the most urbanized territories in the world. Historically, the natural richness and strategic location of these areas resulted attractive for human settlements worldwide. However, these areas are also highly vulnerable due to rapid and unplanned urbanization, land use changes, and extreme climate events. There is an international consensus on the need for new strategies for sustainable development to help cities to mitigate the effects of climate change, as well as adapt to new changing conditions in a context of increasing uncertainty. This paper will explore the specific aspects of urban deltas and coastal areas, from a complexity-based approach, and analyse Nature-based Solutions as alternatives towards sustainable development in these areas.

INTRODUCTION

Coastal areas, especially deltas, are some of the most urbanized territories in the world. It is estimated that half of the world's population has settled within a radius of 200 km from the coasts (Reker et al., 2006). The natural richness and strategic location of these areas have resulted attractive for human settlements for centuries. However, these areas are also highly vulnerable due to rapid and unplanned urbanization, land use changes and extreme climate events. There is international consensus on the need for new strategies for sustainable development to help cities mitigate the effects of climate change, as well as to adapt to new changing conditions in a context of increasing uncertainty. In this sense, Nature-based Solutions are innovative alternatives that are capable of meeting these goals, while changing the existing paradigm of development and flood protection. Historically, coastal protection and water management were seen as a matter of civil engineering, developed in a top-down and centralised way to get control and guarantee rapid and tangible results. Over the last few decades, ecosystem-based initiatives, encouraged by complex-system approaches, have arisen in order to address the same problems from a different perspective, intending to address societal challenges, ensuring long-term benefits for communities, and at the same time, increasing biodiversity and reducing ecosystem loss. This paper will explore the specific aspects of urban deltas and coastal areas, from a complexity-based approach. Then, the concept of Nature-based Solutions (NbS) will be analysed to explore new possibilities of planning, design and governance, without dismissing the risks and obstacles that any novelty concept like this can entail. Furthermore, cases from different parts of the world will be presented to reflect on the potential that NbS can have in terms of the planning, design and management of future coastal cities, with the involvement of civil society in the decision-making process.

DELTAS AS COMPLEX ADAPTIVE SYSTEMS

Deltas can be considered complex adaptive systems, where ecological, social, environmental and many other factors coexist in constant transformation within a context of great uncertainty, exacerbated by climate change (Zagare, 2018). This conception of urban deltas as complex adaptive systems comes from Complexity Theories, and it is related to different aspects. First, urban deltas are open systems in constant interaction with their external environment. Within the system, many subsystems (formed by physical components, social actors and the relationships between them) interact with each other (Zagare, 2018). The interactions are a result of constant adaptation processes between the components and between the system and the environment, which leads to changes in the structure and organization of the system. This process is referred to as co-evolution and takes place in a context of self-organization and path dependence. Self-organization refers to the spontaneous emergence of order without control, that arises from mutual adaptation, while path dependence entails that the direction of each particular change is determined by previous events (Pols et al., 2015). This means that even the smallest component of a system is capable of triggering a qualitative change that can affect the entire system, due to cross-scale interlinkages. As a result of this complex process of constant interactions, the system reaches a dynamic equilibrium where each component is in constant adaptation, but is subjected to possible sudden changes that may lead to a critical transition that will force the system to reach a new dynamic equilibrium (Gladwell, 2000).

Contrary to a reductionist approach, this systemic vision of urban deltas addresses the complexity of interrelationships that takes place in these areas, while identifying drivers of change and possible pathways for planning and design. One of the main drivers is related to increased urbanization, land use changes, and the pressure exerted on the land for economic development purposes (Meyer, 2014). The increase in density in coastal areas and the incorporation of other uses, such as industries, port facilities, and new dwellings entails a higher demand for urban services and implies an increase in pollution and greenhouse gas emissions. Undoubtedly, climate change is the other main driver that increases the vulnerability of these areas. Extreme events are occurring with increasing frequency and intensity than ever before, and the delta´s capacity to cope with them is being affected, due to variability in run-off and sediment transport (Bates et al., 2008). Sea level rise, hurricanes, tsunamis, storm surges, floods, erosion, and other events affect coastal settlements, generating not only economic losses but also casualties. For this reason, it is increasingly necessary to design strategies for climate adaptation as well as for mitigating its effects, guaranteeing sustainable development for communities, as well as contributing to international environmental commitments.

In this paper, the concept of sustainable development is understood as the fulfilment of the aspirations for a better life, "meeting the needs of the present without compromising the ability of future generations to meet their own needs" (WCED, 1988). According to Loorbach (2007), sustainable development is a complex, multi-level and multi-actor process, so a complex systems approach is central to the management of transitions towards sustainability (D. Loorbach & Rotmans, 2006). Knowledge of the dynamics and long-term changes of natural systems, combined with knowledge of the dynamics of external environment and internal interrelationships is fundamental for understanding the properties of the systems, to operate in the fields of planning, design and management in an integral way, instead of carrying out independent actions to address occasional needs dismissing future situations and the nature of uncertainty that may arise.

While the concept of complex adaptive system has taken shape over the last few decades as a logical way to understand environmental-related issues, conversely, during the last century, responses to increased urbanization and climate change effects were based on the development of large-scale infrastructure projects: highways, dikes, pumping and storage facilities, culverts, and drainage networks, among other actions (Chiu et al., 2022; EPA, 2016). Industrialization led to the growth of our cities and with it the demand for infrastructure to meet the needs of operational and economic development. As a result, it was necessary to build communication routes, provide services, and develop urban drainage networks. Many infrastructure projects were carried out without taking environmental characteristics into account. By the beginning and middle of the 20th century, there was no perception of uncertainty related to climate change, and the interrelationship between the different subsystems. Contrary to expectations, infrastructure projects would later have negative and in many cases irreversible effects. This is the case of many urban rivers, which turned into open sewers, and were then culverted, channelled, rectified, and diverted, making them disappear from the surface of the cities.

The need for flood protection also stimulated the construction of dams and barriers, the closure of rivers, and the installation of water pumping and storage facilities, among other works. During the last century, the vision of hard engineering solutions (referred to as "grey infrastructure") as the most legitimate response to urbanization and climate effects was the prevailing paradigm.

Hard infrastructure seemed to be the ultimate response. It was practical, provided short-term benefits, and allowed standardization and thus, replication. However, it also had negative effects. In some cases, it increased water and soil pollution, as well as run-off volumes, given the lack of absorbent surfaces (EPA, 2016). They also required high maintenance and continual renovations to meet increasing demands.

Over the last few decades, scientific evidence has shown that the challenges are increasing. Climate change will worsen, and cities will continue their expansion and densification. Within this context, it has been necessary to find other paths for sustainable development and climate adaptation/mitigation through innovative alternatives that will not become obsolete in the long term, and which are embedded into a sustainable development strategy for coastal areas. These new strategies could bring long-term benefits for communities while increasing biodiversity and reducing ecosystem loss in an integral way. In this sense, a complex system approach seems to be pivotal for planning future coastal cities, being able to operate at different subsystem levels, and generating path-dependent positive externalities at different scales.

A CHANGE OF PERSPECTIVE

The ecosystem approach was first adopted in 1995 in Jakarta, before the second Conference of the Parties (COP 2) of the Convention on Biological Diversity (CBD). It emerged as the main framework for action for the integral management of land and natural resources, which was later published in 2004 (Secretariat of the Convention on Biological Diversity, 2004). Afterwards, the World Bank Report "Biodiversity, Climate Change and Adaptation" (MacKinnon et al., 2008) recognized the role of biodiversity in Climate Change mitigation, adaptation, and water and food security. Since then, new strategies emerged broadening the scope, not only focusing on environmental resources but also on their interaction with society, "recognizing the two-way, dynamic relationships between people and nature" (Mace, 2014). Among these approaches, the concept of Nature-based Solutions emerged in the International Union for Conservation of Nature (IUCN) Position Paper presented at the COP 15 and was then followed by the Report "Natural Solutions" elaborated by the IUCN, The World Bank and other renowned organizations (Dudley et al., 2010; IUCN, 2009). In the latter document, protected areas were suggested to be integrated into broader conservation strategies and mitigation and adaptation plans, including nature as part of a solution itself. In 2012 the term Nature-based Solutions was formally adopted by the IUCN and was a key part of the 2013-2016 Programme of the organization. Later, it was also included at the core of the research and innovation programme Horizon 2020 of the European Commission (IUCN, 2012). In 2016, a definition of NbS was developed by the IUCN (Cohen-Shacham et al., 2016), and then a Global Standard was defined to have a common agreement on the compliance of 8 Criteria (IUCN, 2020a). At present, adaptation through NbS is recognised in the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (Dodman et al., 2021) as a key pathway within the subject "Cities, settlements and key infrastructure". In addition, NbS are aligned with the Sustainable Development Goals (SDGs) adopted by the United Nations Development Programme (UNDP) within the 2030 Agenda (Gerstetter et al., 2020).

NATURE-BASED SOLUTIONS FOR CLIMATE ADAPTATION AND MITIGATION

Nature-based Solutions (NbS) are defined as "actions to protect, sustainably manage, and restore natural or modified ecosystems, that address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits" (Cohen-Shacham et al., 2016). Among societal challenges, it is possible to identify water and food security, human health, disaster risk reduction, climate change mitigation and adaptation, economic and social development and environmental degradation and biodiversity loss (IUCN, 2020b). NbS is considered an umbrella concept since it includes different types of actions, approaches, and interventions, which are capable of responding to one (or more) social challenges. According to Walters (2016), the ecosystem-related approaches associated with the concept of Nature-based Solutions are ecosystem restoration, ecosystem protection, ecosystem management, issue-specific approaches, and infrastructure. Within these approaches, NbS comprise a wide range of interventions that include not only soft actions (regulations, plans, capacity building, etc.) but also hard actions (development of green-blue infrastructures, Sustainable Urban Drainage Systems -SUDS-, etc). *figure 01 — page 42*

Ecosystem-based Adaptation (EbA) and Ecosystem-based Disaster Risk Reduction (EbDRR) are two of the Issue-specific -related approaches that can be included within the global concept of NbS (Cohen-Shacham et al., 2016). They particularly address two of the societal challenges that are related to climate. Nevertheless, these challenges are interrelated with the others, and NbS must be designed integrally, considering the system properties, and interrelationships that are generated within the system and between the system and its environment. This is a very difficult task since it requires scientific knowledge of the system and a high level of governance that includes the participation of the different sectors (academia, government, practitioners, citizen organizations, etc.) throughout the entire process of design and implementation.

In that sense, the Global Standard aims to set criteria to ensure that NbS are developed under common parameters, without overlooking any challenge or stakeholder. Within the Standard's eight criteria, it is possible to discern a complexity-based approach, given the importance that the cross-scale interrelation between different actors and components plays in the design and implementation of NbS, and the role that participation plays within the process. Furthermore, NbS must relate to the national policy on the reduction of greenhouse gas (GHG) emissions, to meet the goals of the Nationally Determined Contribution (NDC) within the scope of the Paris Agreement.

EXAMPLES OF NBS IN DELTAS AND COASTAL AREAS

There is a wide range of NbS cases for climate adaptation in delta areas, at different scales, depending on the type of combined challenges to address. A complexity-based approach to NbS must address integration, inclusiveness, and adaptation as criteria to be followed. Integration refers to the cross-scale, cross-sector, and cross-level interrelationships to integrate systems, subsystems, agents, and networks. Inclusiveness concerns participatory-based approaches enabling joint decision-making and including stakeholders. Finally, adaptation alludes to the generation of planning, design and governance strategies that combined with the existing framework, can allow for the development and implementation of different actions in a flexible way, considering the high degree of uncertainty that characterises these systems (IUCN, 2020b; D. Loorbach & Rotmans, 2006).

The NbS cases presented in this paper were selected taking into consideration the presence of the previously-mentioned criteria: integration, inclusiveness, and adaptation, which implies the acknowledgement of a complexity-based perspective to cities, deltas and coasts. It is important to clarify that some of the cases were carried out prior to the development of the Global Standard to Nature-based Solutions (IUCN, 2020b). For this reason, an ex-post evaluation of the cases with respect to the Standard has not been carried out in this paper but may be the subject of future research.

One of the most renowned NbS cases is the program "Room for the River", developed in The Netherlands between 2006 and 2015 (Rijkwaterstraat, 2017). It implied a radical change of perspective from the previous policy on flood defences, which was mainly based on grey infrastructure. The program "Room for the River" emerged as an innovative alternative to restore delta conditions and natural floodplains while protecting the most vulnerable areas of the Rhine-Meuse-Scheldt delta. The program, developed at a national scale, consisted of 34 projects that created more space for the major rivers to flow through the country, thanks to a series of actions that included the lowering of dams, removal of obstacles, and extension of floodplains, among others (Sijmons et al., 2017).

figure 02 — page 42

The result was a reconfiguration of the space, including green and blue zones for recreation that improved the quality of the area and changed the concept of "flood safety". It also enhanced habitat restoration and multifunctionality in many areas, which now offer different opportunities when the water level is high or low. Some projects, such as the Millingerwaard floodplain excavation, the Lent dike relocation (Nijmegen), and the Munnikenland Buitenpolder dike relocation, also represent a new concept of urban river parks, providing areas for recreational activities and urban services.

figure 03 — page 43

figure 04 — page 43

This program was characterised by cross-scale interventions, and included uncertainty in the process, and expected results, as key variables to consider. Furthermore, according to (Rijke et al., 2012), this program adopted a new multi-level governance approach integrating agencies in different disciplines, at national, regional and local levels, as well as used a mix of centralised (national) and decentralised (regional) decision-making processes. It challenged the traditional vision of water management, which was seen as a matter of civil engineering, as a way of "control". On the contrary, it turned it into an integrated concept, which manages transitions operating as long-term non-linear processes that result from a co-evolution of different values on various scale levels, through a robust strategy of public participation (Rijke et al., 2012; Sijmons et al., 2017). In fact, the case of Nijmegen was awarded internationally in 2011 for its innovative design approach and stakeholder process, and communication strategy (Red-dot, 2011; The Waterfront Center, 2011).

At other scales, NbS can also be applied for coastal protection, focusing on existing natural components, and using "ancient ecosystem engineering" (Meulen & Zetten, 2022). Mangroves historically protected coasts from storm surges, high waves, and winds, and their roots also retained sediments, preventing erosion. Productive activities such as aquaculture and the development of coastal infrastructure led to the removal of mangroves from many coastlines, causing soil and biodiversity loss, floods, and an increase in the vulnerability of the communities. This is the case of the North Coast of Central Java in Indonesia, one of the most populated coastal areas in Asia (Thiele et al., 2020). After losing hundreds of hectares of coasts, mangrove replanting efforts failed to succeed due to the existing sediment disturbance, so it was necessary to find a different solution to the problem. The project developed in Java followed the Building with Nature approach, which "integrates Nature-based Solutions into marine engineering practice, (…) considering both engineering and ecological principles in the design process" (Wilms, van der Goot, et al., 2020).

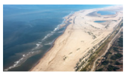
The strategy consisted of the placement of semi-permeable dams built by the community, using local natural materials within an inclusive process of participation (Meulen & Zetten, 2022; Spalding et al., 2014).

figure 05 — page 44

The dams allowed the retention of sediments and the formation of land suitable for mangrove recolonization. Also, a new scheme of Associated Mangrove Aquaculture (AMA) was designed to guarantee the sustainable economic development of the community. This project enhanced bottom-up decision-making and considered multi-dimensional causes and benefits. The analysis of the results shows that within the AMA system, the ponds can be managed more intensively due to an increase in water quality, resulting in 15 times more benefits than the old system (Bosma et al., 2020; Tonneijck et al., 2022). *figure 06 — page 44*

Sand and mud are also used to improve the ecology and water quality as well as protect the coasts from erosion and floods. Several cases in Malaysia and Kerala (India) include sand nourishment to contribute to risk reduction, ecosystem conservation and community livelihood improvement (Van Wesenbeeck et al., 2019). In the Netherlands, sand nourishment has been part of policies for the last 30 years. Before the 1990s, it consisted of coastal stabilization through foredunes which needed to be restored after each storm season (autumn and winter). After 1995, coastal management policy took a more natural direction, aiming at preserving coastal functions and their natural dynamics (Lodder & Wang, 2019). One example is the Zandmotor, a mega project developed on the coast of the Hague (2010) that added 20 million m3 to the coast, covering around 2.5 km2.

figure 07 — page 44



The innovation behind this project was based on the development of a large nourishment located in a specific area, which would slowly change its contour through the action of currents and waves. The natural dynamics would transport the sediments along the coastline, and the process was estimated to have a lifetime of more than 20 years. This implied economic benefits due to the lack of periodic refills, environmental benefits since plants and animal species settled on the Zandmotor, and social benefits because it became a place for recreational activities (Meulen & Zetten, 2022). Sandscaping in Norfolk is another example of sand nourishment, located in the north of the village of Bacton, in one of the main gas terminals of the United Kingdom (UK), which manages one-third of the UK's gas supply. This terminal is close to cliffs and has pipelines buried beneath the beach, which are at risk from coastal erosion (Vikolainen et al., 2017). After evaluating different alternatives, sandscaping proved to be the most cost-effective and has also brought benefits to the community from to tourism and recreation, business support, dwelling protection, and safeguarding of the country's gas supply.

figure 08 — page 44

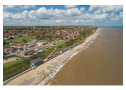
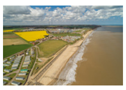


figure 09 — page 45



THE ROLE OF DESIGN

Nature-based Solutions offer new opportunities for the design and management of urban public spaces in urban deltas and coastal areas. Given the great diversity of elements involved in these solutions, the possibilities are endless. Green and blue infrastructure, Sustainable Urban Drainage Systems (SUDS), Water Sensitive Urban Design (WSUD), Integrated Urban Water Management (IUWM), and Stormwater Control Measures (SWCM), among other approaches, whether combined with traditional "grey infrastructure" or not, allow landscape and urban design to get a prominent role. They also encourage the involvement of stakeholders, operating at different levels, system-subsystems-components. Nevertheless, the design should not be restricted to the landscape field. On the contrary, it can play an important role to explore how NbS can be developed and implemented, and how it can connect and integrate other agendas such as infrastructure planning, urban development, production, and transportation, and even be part of the long-term development strategies of the cities (and the countries).

This is the case of Sponge Cities, which start out from the city scale to generate an aggregated impact at the regional or national scale. These cities are a good illustration of a way to increase the resilience of the systems, operate at subsystem levels, contribute to climate mitigation/adaptation, and at the same time improve spatial quality by addressing other societal needs. According to Shannon (2009), the concept of the “City as a sponge” was first adopted in a project for the city of Vinh in Vietnam, to reduce the impacts of seasonal floods through a strategy of low-land/high-land interconnected reconfiguration. Later, the idea of “Sponge City” was adopted in China, where in 2014 the homonymous program was launched to manage water-related risks in their cities that are exposed to frequent flooding (Zevenbergen et al., 2018). Sponge Cities (SC) “are able to adapt, flexible, like sponges, to changes in the environment, such as they absorb, store, permeate and purify rainwater, and (…) make use of the stored water when needed” (Li et al., 2018). Sponge cities regulate the water cycle through the incorporation of big sponge infrastructures including natural elements as a key to restoring the capacity of the cities to cope with rainwater. According to Zevenbergen et al. (2018), the SC concept is closely linked with Water Sensitive Urban Design (WSUD) and can be part of an Integrated Urban Water Management (IUWM) strategy. Within this scope, Green Infrastructure (GI) and SUDS are specific technologies to foster high spatial quality design. Between 2014 and 2016, China’s Ministry of Housing and Urban-Rural Development (MOHURD) selected 30 pilot projects including the cities of Beijing, Shanghai, and Shenzen (Zevenbergen et al., 2018). These approaches have the potential to reduce the risk and have been recognized by the Intergovernmental Panel on Climate Change, which also highlights other cases in Melbourne (Australia) and Semarang (Indonesia) (Dodman et al., 2021).

An example of SC is Sanya Mangrove Park, located on the Linchun River, near the intersection with the Sanya River, close to its mouth in Sanya Bay (China).

figure 10 — page 45

The site is strategic for the environmental interrelation between the inland areas and the sea since it is at the limit the ocean tides can reach, where saltwater meets fresh water. There, the former natural mangroves had been destroyed by urban developments, the land was filled, and grey infrastructure for flood protection was built instead. The site was also degraded due to the presence of debris and rubbish, and the waterways were polluted. Public access to water was hindered due to a lack of pedestrian spatial connections. One of the main objectives of the park was to restore the mangroves and rehabilitate the area in terms of ecological diversity. For this reason, it was necessary to protect the area from the winds and floods of the annual tropical monsoon storms that could harm the mangrove plantation. It was also necessary to guarantee the protection of the plantation from the pollution related to the urban runoffs. As a result, the design consisted of a series of ecotones of interlocked strips with diverse aquatic settings that can manage low and high tides coming from the ocean. It also includes bioswales to filtrate polluted urban runoffs, organized in terraces, creating public places at different levels, and offering a variety of landscapes (Turenscape, 2019b). Similar examples can be found in many Chinese cities, such as the Haikou Meishe River Greenway and Fengxiang Park (Hainan), or the Taizhou Jiangbei Park (Zhejian).

figure 11 — page 45  *figure 12 — page 45* 

Both parks work with the concept of terraces, integrating sewage treatment processes into an ecological system and replacing concrete defences and landfills with wetlands (Turenscape, 2019a, 2019c).

OBSTACLES AND POTENTIAL OPPORTUNITIES FOR THE IMPLEMENTATION OF NBS IN DELTAS AND COASTAL AREAS

The design and implementation of NbS is not an easy task. It requires the integration of actions at different scales within the system and subsystems levels, with the intervention of a multiplicity of social actors, depending on financing mechanisms to make them feasible too. It is possible to identify three groups of barriers. The first group is related to the lack of knowledge about the NbS concept, and awareness of the benefits it can bring to society. There are currently no protocols at the local or national level for the design, implementation and evaluation of these solutions. Scientific evidence on the results of these interventions is being developed but is still in formats that may not be accessible to all stakeholders, hindering knowledge transfer between science, policy and planning (Egusquiza et al., 2019). To overcome this obstacle, it is necessary to implement innovative communication strategies and generate scientific documents accessible to all sectors, including good practice manuals, guidelines, and educational documents for schools, to raise awareness in the community. Governmental officials also need to be trained regarding processes, techniques, and concepts.

The second group of obstacles is related to governance. Governance is complex in itself, especially in deltas and coastal areas, where environmental conservation and the need for socio-economic development collide. NbS require coherence between short-term needs and long-term goals. Local authorities often need to show results within short action cycles and make decisions without considering long-term sustainable plans (sometimes those plans do not even exist). Furthermore, the complexity of governance structures undermines coordination between levels of decision-making and departments, generating “sectorial silos” which are not compatible with the multilevel, multiscale and multidisciplinary approaches that NbS require in order to be fully implemented (Egusquiza et al., 2019; Kabisch et al., 2016). Lack of public participation and top-down processes are also obstacles, as well as an unsupportive and rigid legal framework. Knowledge transfer (previously mentioned), capacity building and collaborative governance include a wide range of instruments and methods which can generate spaces for social mobilization that can be anchored within the planning and institutional existing framework (Zagare, 2018).

The third group concerns economic barriers and how they are interrelated to knowledge and governance. The source of funding for NbS varies depending on the environmental domain, the technology required, and the scale of the project. Small-scale NbS such as urban agriculture or community gardens may have a high percentage of community funding, in some cases through crowd-funding instruments (McQuaid, 2019). Green roofs, vertical gardens, rain gardens, and other small interventions can also be funded by the private sector (owners), indirectly, through legal instruments (subsidies, incentives, or exemptions). Other infrastructure projects related to larger private developments can be financed by the developers if the respective legislation has instruments that demand them for environmental compensation. With regards to large-scale NbS projects, such as SUDS, IUWM, SC or other interventions, according to Mulder et al. (2021), around USD 133 billion is invested in these projects worldwide each year. In these cases, the public sector (mainly domestic governments) is responsible for more than 90 per cent of the investment, while the private sector (NGOs, biodiversity offsets, sustainable supply chains, etc.) contributes the rest. One of the reasons for this imbalance is that NbS is a new concept that includes environmental benefits, in which revenues and risks are not well estimated nor communicated (Egusquiza et al., 2019). Another reason is that NbS have long-term benefits, which in many cases discourage private participation. Given the restricted budget that characterises local governments, investment in NbS is not always a priority. To counteract this situation, it is necessary to explore innovative business models that include both sectors to attract investors and which allow the projects to scale up (Egusquiza et al., 2019). It is also a key factor to align the long-term vision of the investment with the general goal of the project and to produce a cost-benefit analysis. Another option for local authorities is to access funding through international and regional adaptation and mitigation multilateral funds, considering that NbS are an opportunity to contribute to National Adaptation Plans (NAP) and Nationally Determined Contribution (NDC) for reducing greenhouse gas (GHG) emissions, to meet the Paris Agreement and the Sustainable Development Goals (SDGs) adopted by the United Nation Development Programme (UNDP). The United Nations Framework Convention on Climate Change (UNFCCC), and the European Commission, among other multilateral agencies, include instruments for financing adaptation and mitigation (Instituto para la promoción de la diplomacia parlamentaria en el sistema interamericano, 2021).

Alongside the benefits of NbS, negative externalities can emerge. Recent evidence suggests enhancing greenspace and investing in infrastructure improvements to regenerate degraded urban areas may lead to a rise in property values. This phenomenon can lead to a subsequent displacement of low-income local communities followed by the arrival of high-income groups (Frantzeskaki, 2019; Scott et al., 2016). This process is called "eco-gentrification" and implies a high risk given that, according to the core principles of NbS and the IUCN Global Standard (Cohen-Shacham et al., 2019; IUCN, 2020b), these actions must address social challenges, within a process of inclusive governance. New approaches for regeneration programmes must include stakeholders from the beginning of the process and allow them to actively participate in the co-design of the areas, to legitimate the process through citizen engagement. It is therefore important to regulate social programmes for the area and legal instruments to avoid gentrification, especially when the communities are indigenous people, minorities and vulnerable populations (IUCN, 2020b). Another risk is associated with the concept of "greenwashing". Many of the biggest enterprises and developers that contribute to greenhouse gas (GHG) emissions invest in natural solutions to counteract the negative externalities they cause, instead of investing in net-zero carbon plans. These enterprises (and the nations that subsidise them) do not carry on a systemic change, but they continue their operations, as usual, considering NbS as carbon "offsets" (Seddon, 2022). As previously noted, NbS must be considered within a general plan for the reduction of greenhouse gas (GHG) emissions, avoiding a limited perspective of impacts and compensations. It becomes crucial to rely on scientific, practical and technical knowledge developed by organizations and institutions, such as the IUCN Global Standard (among other documents), in order to guarantee that the risks are minimised. NbS must be embedded within a national policy on greenhouse gas (GHG) emissions reduction, to meet the goals of the Nationally Determined Contribution (NDC) set by each nation.

CONCLUSIONS

Nature-based Solutions for climate adaptation and mitigation in deltas and coastal areas offer a limitless range of possibilities for planning and design. There is therefore a definite need for a change in the paradigm of urban development towards a more sustainable approach. Deltas and coastal areas must be understood as complex adaptive systems, where all the components and subsystems are interrelated within a context of high uncertainty. This concept must be present in planning, design and governance processes in order to address societal challenges of the present and ensure possibilities for the future. Consequently, NbS, like any other urban strategy, must be undertaken in an integral, flexible way, with the active participation of stakeholders to legitimate the process. Participation is a central factor from the theoretical perspective since it is related to the self-organization that characterises complex systems. Furthermore, it is also important from the practical realm, to generate real changes that can be maintained in the future and achieve a paradigm shift in urban growth in coastal areas from a bottom-up perspective. Finally, it is necessary to consider that NbS are broad actions to address societal challenges including climate change adaptation and mitigation. These interventions must be included in broader strategies for the reduction of greenhouse gas (GHG) emissions, and no social challenge should be dismissed since they are all part of the problem, but also the solution.

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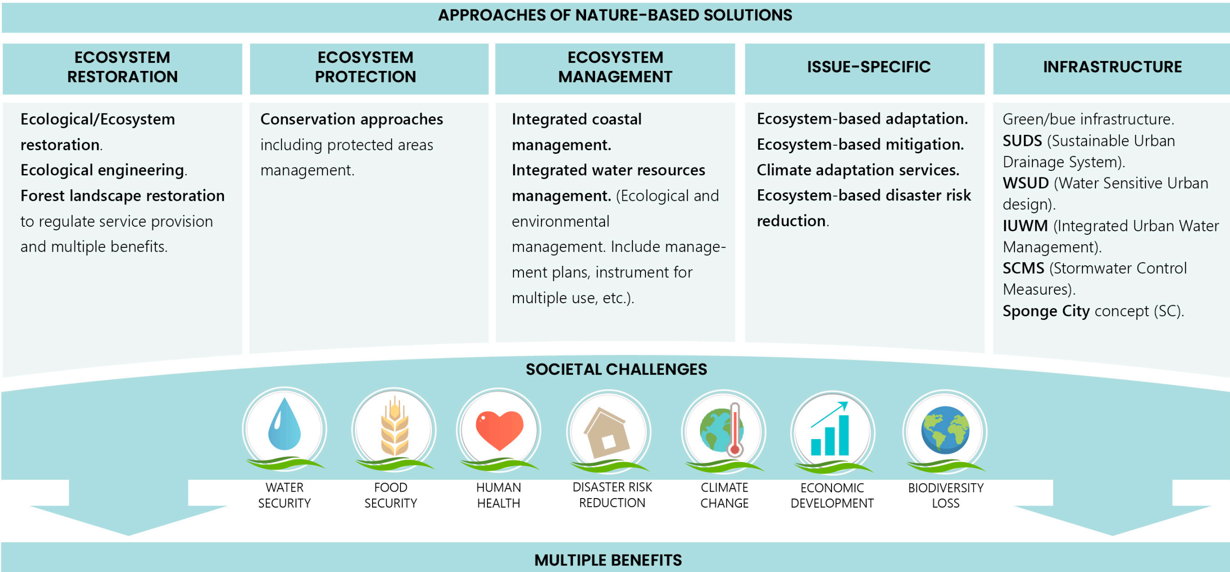

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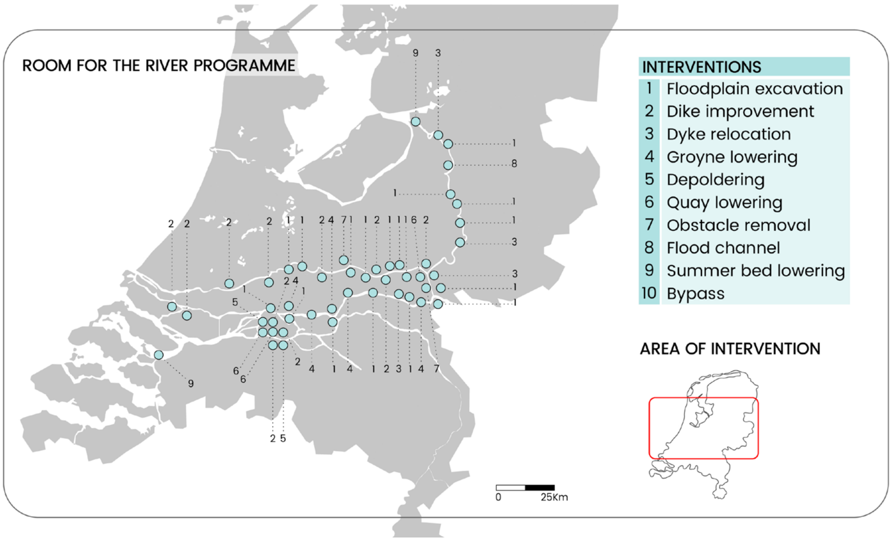

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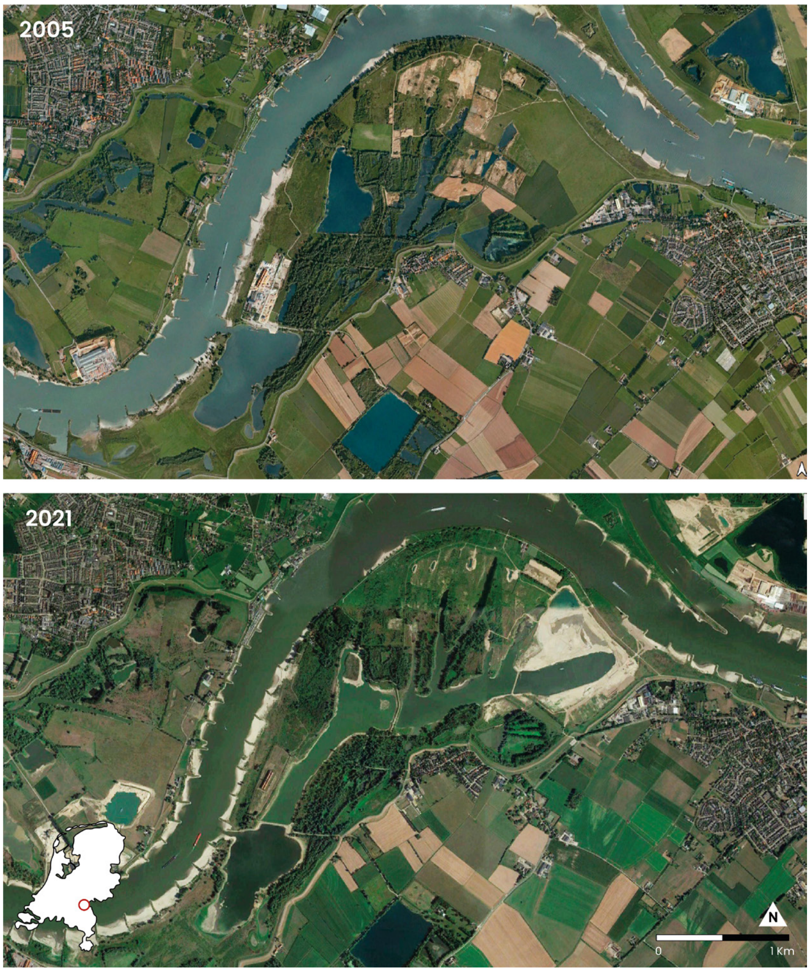

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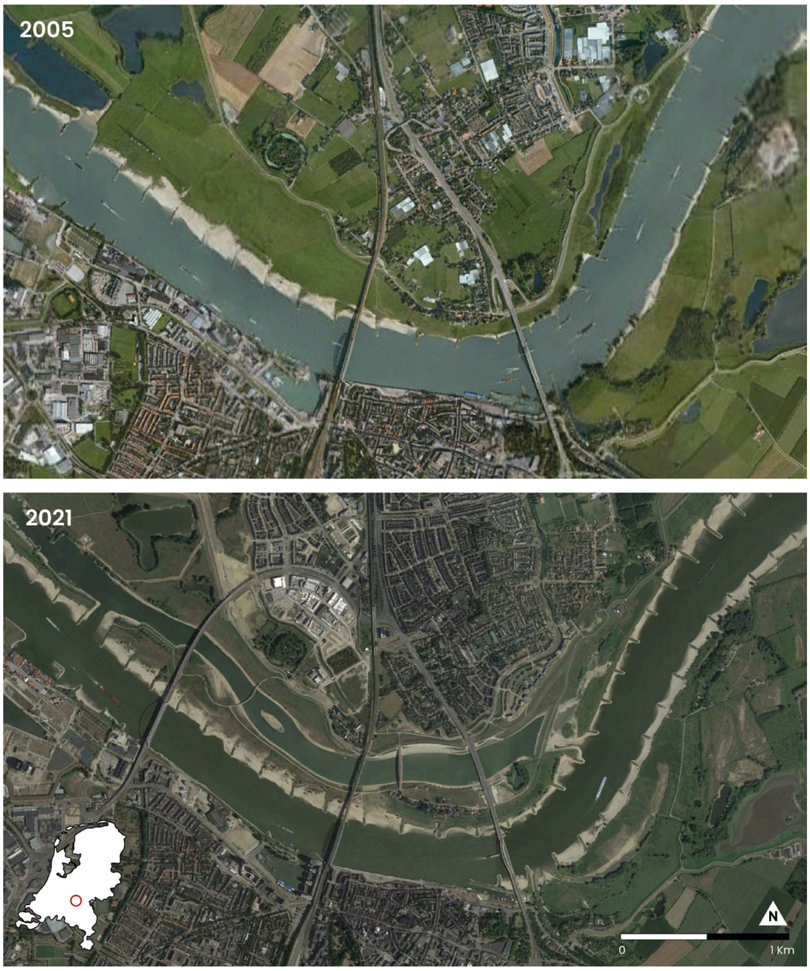

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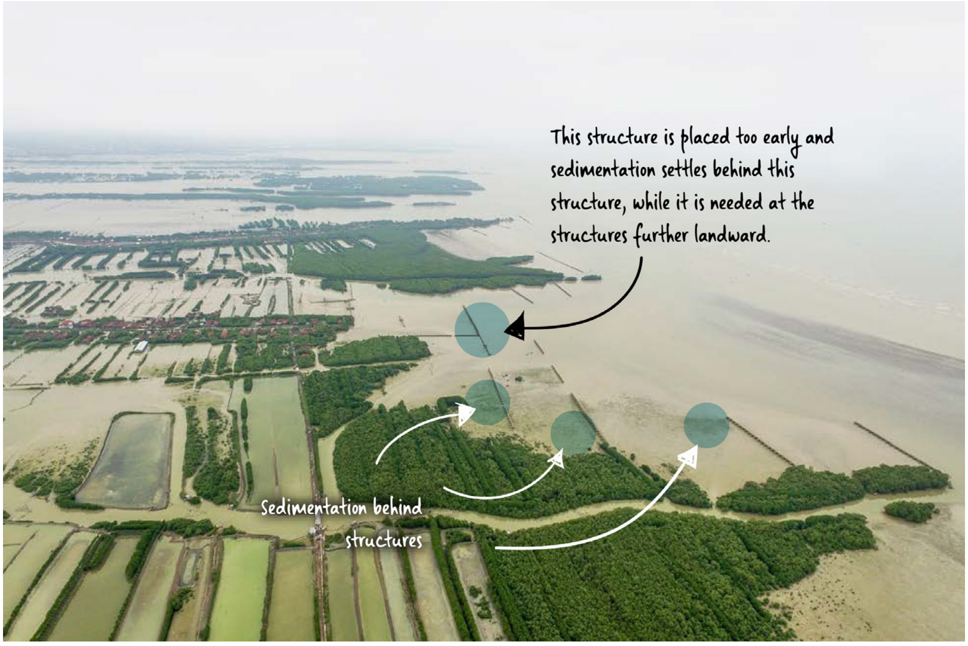

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