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Towards Climate Resilient Coastal Cities: a Framework to Deploy Nature-Based Solutions in the Urban Planning Strategies of the North Coast Cities in Egyptp

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1 ABSTRACT

Coastal zones of the Mediterranean region are severely affected by the effects of extreme climatic events, along with human-induced pressures, which causes their growing vulnerability. That leads to the urgency for sustainable and resilient long-term strategies for coastal development projects. In Egypt, the North Coast zone is considered a hotspot for climate-related changes. It is undergoing a series of new urban development projects expanding the urban areas along the coast of the Mediterranean Sea. As anthropogenic consequences along its coasts increase, the need for sustainable Nature-Based Solutions (NBS) will increase accordingly.

Recently, adaptive management strategies have been considered an important tactic to atone the unknown environmental conditions that coastal areas struggle with. Adaptive management was exploited to lessen such uncertainty by incorporating adaptive management into climate change adaptation strategies. In response to this need, this paper proposes a framework for nature-based solutions. It consists of four stages, it is founded on a novel approach that combines system analysis and building scenarios. Moreover, the first stage mainly depends on using the structure of the DPSIR (Driving force–Pressure–State–Impact–Response) model to improve ecosystem services and generate the evidence-base for the environmental, social, and economic benefits of nature-based solutions for implementation. The last two steps mainly reflect the adaptive management process and it is well-suited to capitalise on the transformational character of nature-based solutions' as it encourages "breakthrough" leaps rather than incremental improvements.

In essence, this framework aims to employ nature-based solutions in urban planning strategies to increase the climate resilience of coastal cities and. in particular, to identify suitable and less suitable strategies to be deployed in each zone. The framework has yet to be tested in a real-world case study; instead, this paper intentionally focuses on describing its structure, goals, and methodology, discussing its features, and framing its role from a climate resilience standpoint. As a result, the paper lacks a results section. Finally, conclusions are drawn regarding its potential adoption and further development.

Keywords: climate change adaptation, ecosystem services, nature-based solutions, adaptive management, Climate resilient

2 INTRODUCTION

Climate change is a real challenge that the world is facing nowadays (IPCC, 2014). Rapid urbanisation and increasing anthropogenic activities cause increasing climate change impacts and consequences that lead to improper and imbalanced functioning in the socio-ecological system, increasing vulnerability and reducing resilience (Mahmood, Zhang, Li, & Rahman, 2021). Moreover, most coastal cities are already dealing with noticeable changes from sea level rise, increasingly severe and more frequent coastal storms, and escalating loss of coastal resources such as fisheries and coral reefs, since pollution leads to warming and acidifying waters and other stressors to severely degrade coastal ecosystems. Therefore, researchers are focusing on promoting social-ecological resilience to face the climate change impact on coastal communities (Garmestani et al., 2019). Accordingly in the socio-ecological system, climate change resilience is defined as an element which refers to the capacity to absorb stress and maintain functions by adapting and evolving into a sustainable configuration for future climate change impacts (Hayes, Desha, Burke, Gibbs, & Chester, 2019).

In 2015 the UN proposed 17 Sustainable Development Goals (SDGs) which are considered the benchmark of progress of all signatory countries worldwide to promote sustainability by 2030 (UN, 2017). Most of the SDGs urge taking action to mitigate and adapt to climate change impacts such as Goals 1-3,6,7,9,11 and 13. Furthermore, SDG-11 (Sustainable cities and communities) seeks greater efficiencies in urban planning and management practices that address ageing infrastructure and ongoing air, water, and soil pollution, while SDG-13 promotes directly enhancing the adaptive capacity and resilience to climate change (UN, 2017).

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Meanwhile in Egypt, the Sustainable Development Strategy (SDS) presents Egypt Vision 2030 which has followed the Sustainable Development Goals (SDGs) as a general framework for improving the quality of life and welfare, taking into consideration the rights of new generations in a prosperous life; thus, dealing with three main dimensions which are environmental, economic, and social dimensions (UNDP, 2018). Hence, climate change resilience became a vital factor of sustainable development and is notably important to governments, policymakers, researchers, and educators. Lately, researchers globally advocate that nature-based solutions address societal challenges such as climate change and provide biodiversity benefits. However, the potential of nature-based solutions in building climate resilience and addressing climate change adaptation through urban planning in coastal cities has remained research rhetoric.

This study examines the effectiveness of nature-based solutions for tackling climate change adaptation and enhancing climate resilience. As a result, the study begins by reviewing the body of knowledge already available on climate resilience and nature-based solutions. The complexity and multifunctional features of nature-based solutions are then highlighted. The effectiveness of nature-based approaches in fostering climate resilience and adaptation is then examined. As a result, a framework is created that concentrates on the application of nature-based solutions and how it responds to climate resilience. To build climate resilience, this research stresses the use of nature-based solutions in local urban design as an effective urban policy instrument. According to this research, it is essential to include nature-based solutions into local urban planning. Furthermore, the framework has yet to be tested in a real-world case study in the Northwestern Mediterranean coastal zone, more specifically the New Alamein City. Instead, this paper intentionally focuses on describing its structure, goals, and methodology, discussing its features, and framing its role in terms of climate resilience. As a result, the paper lacks a results section where the findings of its potential application to a study area should be discussed, as well as the strengths and weaknesses of the framework. Finally, conclusions are drawn regarding its potential adoption and further development.

3 MATERIALS AND METHODS

A systematic literature review was conducted to develop the framework's scope and content. It was conducted using the databases Google scholar, Web of science and Scopus with the keywords "nature-based solutions" AND "framework" being used. The content was written in English and published until July 2022. The articles chosen was that proposed a novel framework and/or applied it to a case study/studies.

The following information was extracted from the selected publications: approach type (conceptual, practical, or both), sustainability dimension addressed (environmental, social and economic,), settlement type (urban, peri-urban, rural, or general). Beisdes, if the framework proposed a qualitative or quantitative assessment, and the purpose of the framework regarding Nature-based solutions (planning, evaluation, or both), a literature review was conducted to identify the main concepts related to Nature-based solutions, the main themes included, and the main gaps. Besides reviewing all strategies and policies of the Egyptian government regarding the climate change adaptation and mitigation actions in general and specially the Northwest Coast of the Mediterranean during the last decades. Identifying the main actions related to climate change impacts and main gaps. All of these were incorporated into the framework created here.

4 THE EGYPTIAN MEDITERRANEAN COASTAL ZONE AS A CLIMATE CHANGE HOTSPOT

The Mediterranean region and in particular its coastal zones are severely affected by impacts of extreme climatic events for example storm surges, coupled with human-induced pressures such as uncontrolled building on coasts, resulting in growing vulnerability. (Satta, Puddu, Venturini, & Giupponi, 2017). Giorgi (2006) referenced that based on the results of global climate change projection models, the Mediterranean region was identified as one of the most vulnerable to climate change and as a key "Hot-spot". The Mediterranean is highlighted in the International Panel on Climate Change (IPCC) report as one of the regions that are most susceptible to the effects of global warming. The necessity of evaluating potential climate change effects on this sensitive region, which will become substantially warmer and drier, is highlighted by the background of global warming. (IPCC, 2013).

Depending on the sub-region, an increase in air temperature of 1.5 to 4°C was seen in the Mediterranean basin. A warming trend can be observed in North Africa as well, albeit it is more challenging to quantify due to the observing system's more sporadic nature. Besides, sea-level rise (SLR) will lead to increases in coastal

flood and erosion risks along the entire Mediterranean coast. (UNEP/MAP, 2017). Policies for the Mediterranean country‘s sustainable development need to mitigate these risks and consider adaptation options, although currently, it lacks adequate information, specifically for the most vulnerable southern Mediterranean societies, where fewer systematic observation schemes and impact models are based (Cramer et al., 2018; Milano et al., 2013). Utmost climate models point to a significant shift toward drier conditions during winter and spring when southern Mediterranean countries receive the bulk of their annual precipitation. Coupled Model Intercomparison Project phase 5 (CMIP 5) (Taylor, Stouffer, & Meehl, 2012) Global Climate Models (GCMs) project predicts that annual precipitation decreases could locally reach 40% under an (RCP8.5) higher emission scenario i.e. business-as-usual scenario (Zappa, Hoskins, & Shepherd, 2015). Accordingly, this would severely affect the habitability and stability of the basin in the next coming decades (Dubrovský et al., 2014).

4.1 The Northwestern coast of Meditternean Climate change impact

The Northern Egyptian coastline extends 1000 km along the southeast of Mediterranean Sea as shown in Figure 1 (Iskander, 2021). Egypt’s coastal zones are expected to be affected by a 50 cm sea level rise that will affect 2 million people and cause land and real estate losses worth about 35 billion US$ (Agrawala et al., 2004). The overriding roots are the rapid infrastructure and urban development, increasing tourism and recreational activities, pollution from residential, agricultural, commercial, and industrial activities and the anticipated impact of climate change and sea level rise, significantly on the low-lying areas (Kafrawy & Soliman, 2012). These are mainly anthropogenic-induced stressors. These will aggravate vulnerability and add to the impacts of climate change and sea level rise that will manifest themselves in sectors such as agriculture, irrigation, population and health, as well as infrastructure shown in Table 1 (El-Masry, El-Sayed, Awad, El-Sammak, & Sabarouti, 2022; Kafrawy & Soliman, 2012)

Figure 1: The north coast of Egypt extended on the Mediterranean Sea as well as The northwestern coast zone is highlighted.

Aspects		SLR	Saltwater intrusion	Extreme storm occurrences	Increase water temperature	Change of acidity
Ecosystem/Nature	Erosion	■		■		
	Soil salinization	■	■		■	■
	Endangered Ecosystem	■	■	■	■	■
	Land subsidence	■				
Socio-economic activities	Agriculture	■	■	■	■	■
	livestock	■	■		■	■
	Fisheries	■	■	■	■	■
	Industry	■		■		
	Infrastructure	■		■		
	Human settlement	■	■		■	■
	Health	■	■	■	■	
	Water resources	■	■	■	■	■

Table 1: Impacts of climate change on the Egyptian coastal cities (Ismail, 2018).

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Furthermore, west of Alexandria city, cities are stretching along 525 km of the Northwestern Coast of Egypt on the Mediterranean Sea as shown in Figure 1. This propitious region will be the focus of the study since it has attracted in the past many touristic projects with massive investments (Elsharnouby, Soliman, Elnaggar, & Ouda, 2012). However lately, Egypt is focusing on the Northwestern Coast zone, a part of Egypt Vision 2052 to build new urban settelments along the coast. Many proposals identified this region as a potential development zone, it reaches a depth of about 40 km from the shoreline and is supposed to include new urban settlements to attract more population to settle on the North Coast such as the New Al-Alamein City (Attia, Shafik, & Ibrahim, 2019). Thus, the different social and economic development areas along the Mediterranean coast of Egypt are under immense and continuous pressure. Due to climate change and expanding urban and tourist development in new locations vulnerable to natural disasters and other factors, the disaster risks are predicted to grow by 2030. There will be increased hazards of coastal erosion, marine submersion, and water scarcity, as well as increased dangers of land subsidence, seismic activity, and flooding (Kafrawy & Soliman, 2012). Therefore, a compelling need emerges to understand coastal zones in the Mediterranean region and how they could evolve under the effects of climate change and to develop methodologies that can assess the resultant vulnerabilities and risks. Proactive adaptation to these hazards is essential for maintaining the functions of coastal zones. Nature-based solutions for shore protection such as beaches and shore nourishment as well as dune or wetland restoration are becoming a more common alternative to hard structures (Cramer, Guiot, Marini, Secretariat, & Bleu, 2020).

4.2 Egypt's National Strategy for Adaptation and Mitigation to Climate Change Risks

The Egyptian government's concern for climate change has resulted in the development of a national strategy addressing the phenomenon of climate change based on the sectors affected and those influencing the issue of climate change. The first level is concerned with adaptation to climate change, while the second is concerned with mitigating its severity. Furthermore, some efforts have been made to protect coastal areas and improve the resilience of these zones. Egypt undertakes these efforts primarily for current development and environmental priorities, which are synergistic with climate change adaptation. Nonetheless, attempts are mostly limited to "hard" adaptations, which, given the significance of the obstacle, are still somewhat inadequate in terms of covering vulnerable regions (Kader & Haron, 2020).

Also, Egypt submitted its Nationally Determined Contribution (NDC) and Third National Communication (NC3) to the UN Framework Convention on Climate Change (UNFCCC) in 2016, in support of its efforts to achieve its development and economic goals and increase its adaptive capacity to climate change. Egypt's NDC aligns with the country's overarching goals of reducing vulnerability and poverty while achieving long-term sustainable economic development. Key areas of focus include environmental sustainability, water resources, energy, sustainable land management, agriculture, and health (WBG, 2020). The Egyptian government recently launched the National Climate Change Strategy to support the transition to a greener, climate-resilient economy. The private sector is increasing its adaptation efforts and will play a critical role in this transition. Egypt has also issued the region's first sovereign green bond to finance projects in clean transportation and sustainable water management in order to develop the green finance market. Egypt is also coordinating global action on climate adaptation, mitigation, and finance as the host of COP27.

Nevertheless there is still some research and institutional gaps to improve the government strategies to build resilience to climate change, these gaps are:

4.2.1 Research gaps

- Improve understanding of key vulnerabilities and development impacts associated with projected climate change trends in Egypt, as well as potential soft adaptation responses.
- Increase public, scientific institutions, and local communities participation in planning and management.
- Strengthen environmental monitoring capabilities for more effective environmental management.
- Improve understanding of the impacts on Egypt's coastal zones, including investment in risk assessments and soft adaptation options.
- More research is needed to understand the vulnerability and adaptation of Egypt's biodiversity to the effects of climate change.

4.2.2 Institutional gaps

- Ensure that the National Environmental Strategy goals are integrated into sectoral and regional plans, as well as financial opportunities with donors.
- Systematic observations of sea surface temperature, coastal land use, and sea level variations must be institutionalised to ensure that results are available to the scientific community and policymakers.
- Promote energy efficiency options by improving financing options and providing legal support for public-private partnerships.
- Implement cross-sectoral climate-smart nature solutions for Egypt's urban planning and water management sectors at the national and sub-national levels.

5 DEFINITIONAL AND CONCEPTUAL ASPECTS OF NATURE-BASED SOLUTIONS (NBS)

While there is still an ongoing debate on defining Nature-based solutions (Nesshöver et al., 2017), the definitions elaborated by the International Union for Conservation of Nature (IUCN) and the European Commission (EC), as most conceptualizations, build upon or refer to (Calliari, Staccione, & Mysiak, 2019). Nature-based solutions are defined by the European Commission as "living solutions inspired by, continuously supported by and using nature, which is designed to address various societal challenges in a resource-efficient and adaptable manner and to provide simultaneously economic, social, and environmental benefits" (European Commission, 2015). IUCN defines nature-based solutions 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, Walters, Janzen, & Maginnis, 2016).

The IUCN definition provides and encompasses eight foundational principles which are the consideration of local natural and cultural contexts, application at the landscape scale, and a forward-looking attitude in considering the evolution of ecosystems and associated benefits, besides the endorsement of nature conservation norms, fairness, and equity in delivering societal benefits (Cohen-Shacham et al., 2016). On the other hand, the European Commission's definition embraces locally adapted, cost-effective, and resource-efficient solutions that are "inspired by, supported by or copied from nature" and "simultaneously provide environmental, economic and social benefits and promote building resilience" by bringing "more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes" (European Commission, 2015).

Conclusively the common factor is a recognition of the role that nature can play in tackling major societal challenges, such as disaster risk management, and climate change adaptation and mitigation. The term "solutions" implies a problem-centred approach, thus the identification of problems or challenges that could be effectively addressed by NBS is a key aspect of this approach (Potschin et al., 2016). Another shared distinctive trait that concerns the capacity of NBS is "multifunctionality" (Kabisch et al., 2016), in other words, to deliver simultaneous benefits to society, the economy and the environment (Albert, Spangenberg, & Schröter, 2017). Moreover, it builds upon an anthropocentric view of the benefits that natural resource management can bring to humans (Nesshöver et al., 2017). In particular, the European Commission emphasises the way NBS can contribute to the application of participatory processes for co-design, co-creation and co-management (Pauleit, Zölch, Hansen, Randrup, & Konijnendijk van den Bosch, 2017), and reliance on multidisciplinary, evidence-based strategies (Nature, 2017).

5.1 Building Climate Resilience for coastal cities by nature-based solutions

Climate resilience is based on two interacting concepts: "adaptation", and "mitigation (Christopher M Raymond et al., 2017). In the case of nature-based solutions, which involve elements of ecosystems, the two concepts are closely linked as any adaptation of an ecosystem can further influence the mitigation potential, for example by sequestering carbon in vegetation, with an overall dramatic effect on climate resilience. Furthermore, there is a growing scientific and engineering interest in investigating how natural processes can provide management solutions to coastal environment degradation and vulnerability. Climate change and associated sea level rise, along with drivers such as subsidence, reduced sediment supply, and coastal squeeze, are major risk factors for the sustainability of coastal systems. Using natural processes to deal with these risk factors is considered a challenging task (Slinger, Stive, & Luijendijk, 2021). Nature-based

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solutions include using existing natural systems (for example, protecting a marsh), managing or restoring those systems (for example, restoring a marsh), or developing new systems (e.g., combining mud flats, marshes, and concrete levees to create a horizontal levee) (Cohen-Shacham et al., 2016). All of these natural-based solutions types can help to improve coastal resilience and risk reduction by utilising natural processes and landforms to protect both ecosystems and the built environment (Whelchel, Reguero, van Wesenbeeck, & Renaud, 2018). They can provide not only protection from sea-level rise and storms (Arkema et al., 2013; Shepard, Crain, & Beck, 2011), but also mitigation of climate change through carbon sequestration, recreational opportunities, habitat for key species, and other benefits (Bilkovic, Mitchell, Mason, & Duhring, 2016; Gedan, Kirwan, Wolanski, Barbier, & Silliman, 2011). As illustrated in Figure 2 the different Nature-based Solutions strategies that could be implemented in coastal cities to prevent coastal erosion and urban flooding. These advantages—ecosystem services or contributions of nature to people—help connect healthy, functioning ecosystems to human well-being (Guerry et al., 2015; Guerry et al., 2022).

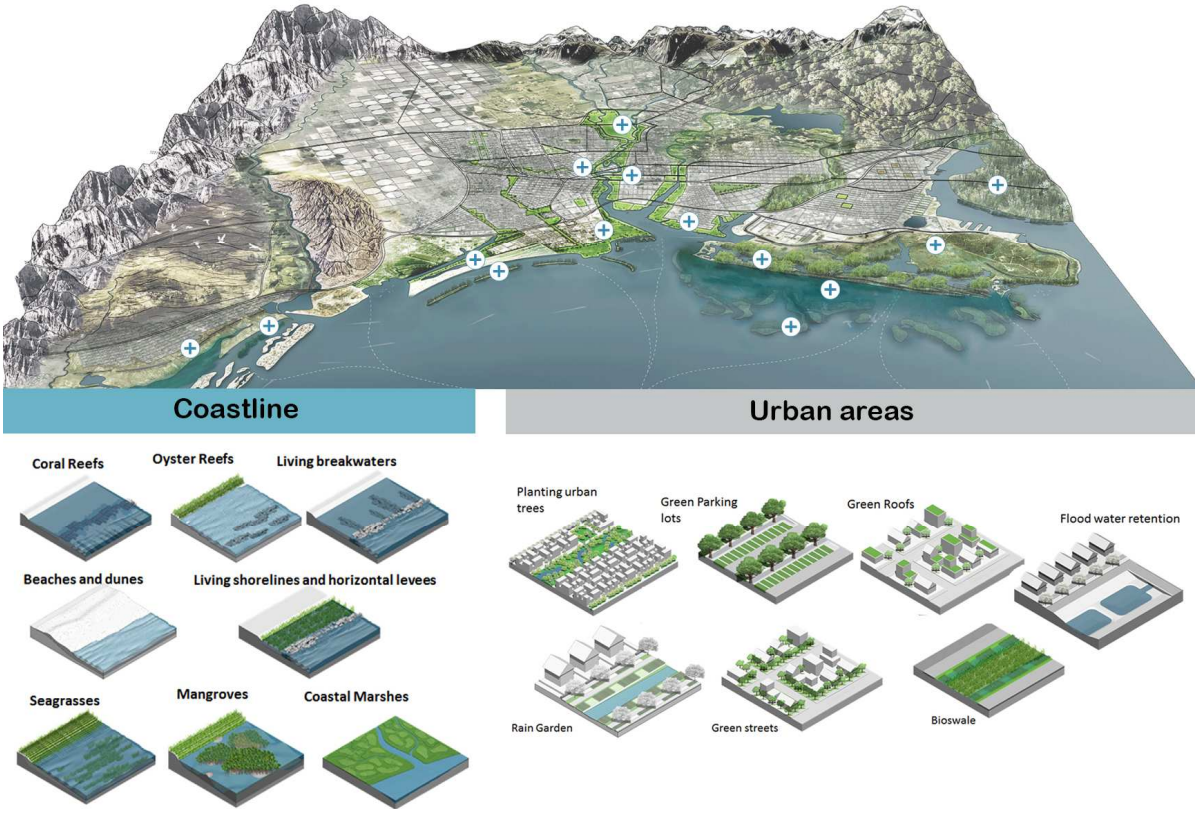

Figure 2: Illustration depicting the diversity and location of nature-based solutions approaches across coastal and urban landscapes. Adapted from www.nrcsolutions.org.

5.2 Right scale for implementation

One of the major issues in implementing Nature-based solutions for urban climate resilience and in understanding their potential impact and effectiveness is related to the scale of intervention. Action on climate mitigation can span the micro level of a single building, the meso level of the whole city or country and the macro level of the entire planet, though it has essentially a macro (global) scale effect by affecting global concentrations of greenhouse gases. Climate adaptation is more often planned and implemented at the meso (national) to micro (local) level, and the impacts are also at these levels. There are some common actions and indicators, but also some that are specific to the different scales of climate action to be addressed, as identified below. To reduce global greenhouse gas concentrations, nature-based solutions for climate resilience can either be macro-scale mitigation or meso- and micro-scale adaptation. Meso-scale adaptation involves planting vegetation to improve the local or regional microclimate through cooling, shading, and shelter (Christopher M Raymond et al., 2017).

5.3 Transdisciplinary collaboration for Nature-based Solutions Implementation

For building resilience understanding the interconnectedness of citizens, physical spaces, and policies as a social-ecological system (SES) is crucial. It provides a framework for developing urban resilience and sustainability approaches (Vandergert, Collier, Kampelmann, & Newport, 2016). Emerging research suggests that multi-stakeholder experiments that bring together expertise from individuals, organisations, agencies, and institutions at multiple organisational levels can promote a social-ecological approach. The outcomes of these collaborations must eventually be translated into the planning/policy framework via adaptive governance processes to ensure that transformation opportunities are not missed. Thus, this paper demonstrates how nature-based solutions can support multifunctional ecosystem service benefits (Connop et al., 2016; Folke, Hahn, Olsson, & Norberg, 2005; Wilkinson, 2011).

Furthermore, while significant progress has been made in the design and testing of ecosystems and their role in risk mitigation, these solutions have yet to be fully evaluated and standardised. As a result, some nature-based climate adaptation projects have been poorly designed, resulting in ineffective and unsustainable outcomes. As with engineering solutions, there is no "one size fits all" approach because climatic, ecological, and hazard characteristics vary and are frequently poorly understood. However, the traditional infrastructure sector has a long history of fully developed protocols and standards, whereas nature-based solutions are emerging approaches that require the same level of investigation of lessons learned (Connop et al., 2016; Folke et al., 2005; Wilkinson, 2011) and standard development. As a result, guidelines and standards for nature-based solutions must be developed to assist project designers, implementers, funders, evaluators, and others involved in project development. The guidance also aids in developing a shared understanding of the likely effectiveness and risk reduction outcomes. Accordingly, this framework aims to be a first step toward standardisation.

5.4 Nature-based solutions frameworks

There aren't many frameworks for recognising, evaluating, and guiding the design and implementation of cross-sectoral initiatives and policies, as well as the role and co-benefits of nature-based solutions. An illustration of a conceptual framework for evaluating the co-benefits of nature-based solutions across components of socio-cultural and socio-economic systems, biodiversity, ecosystems, and climate was established by Christopher M. Raymond et al. (2017). After reviewing numerous documents from science and practice served as the framework's primary source of inspiration. Following the database searches, each article was screened for eligibility and retrieved the full-text version of each potentially relevant reference. The systematic literature review criteria were met by a number of articles. Most of the articles were published in 2019, followed by 2020, and a few of them in 2017 and 2018. There was no time limit for the initial search, and the first Nature-based Solutions framework was published in 2017, demonstrating the novelty of this research field (Christopher M Raymond et al., 2017). The articles were divided into two categories: "conceptual" papers in which the frameworks were not applied in practice such as Cohen-Shacham et al. (2019) and "practical" papers in which a case study/experience related to the framework's application was presented such as Lafortezza and Sanesi (2019). Some articles addressed both conceptual and practical aspects of the NBS framework. In terms of the location or type of settlement to which the analysed frameworks can be applied, the majority were general (applicable to any context), some applied to an urban context, and the least of them applied to a rural context. There were no studies that specifically looked at "peri-urban" areas. The environmental and social dimensions were the concern of the majority of the research (Dumitru, Frantzeskaki, & Collier, 2020), those two pillars of the three pillars of sustainability were used in more frameworks than the economic dimension.

Accordingly, creating robust monitoring and evaluation frameworks to assess the impacts of nature-based solutions will enable cities to evaluate the strengths and weaknesses of specific interventions in achieving strategic city goals. As part of a broader movement toward evidence-based policy and management, various stakeholders are increasingly demanding more evidence of policy effectiveness. It will also provide an essential tool for the adaptation of design and implementation features, thereby increasing their performance. It may also strengthen the case for investments in Nature-based solutions, as most Egyptian cities struggle to persuade investors that climate adaptation strategies especially soft solutions such as nature-based solutions can meet the diverse objectives and interests of their stakeholders. Finally, for mainstream change to occur, rigorous evaluation is required. Robust evaluation is required for a shift in mainstream approaches to urban

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resilience and regeneration planning, which are still dominated by redundancies resulting from viewing ecological, social, and economic objectives as distinct and sometimes contradictory, as reflected in the silo-thinking of urban policy practice.

6 PROPOSED FRAMEWORK FOR IMPLEMENTING CLIMATE PROOF NATURE-BASED SOLUTIONS IN COASTAL CITIES

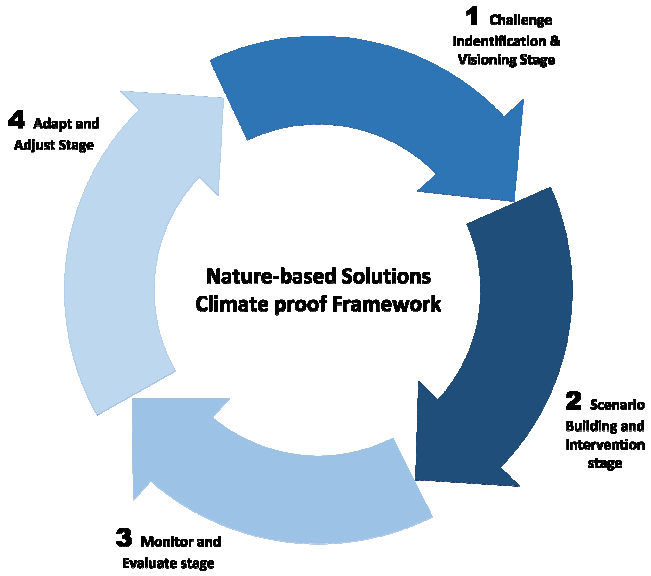

Figure 3: Schematic diagram of the framework showing different stages. (By Author)

As mentioned earlier scholarly work has highlighted the need to assess the social implications of Nature-based Solutions and how they link to just and equitable cities (Haase et al., 2017). This paper focuses on a framework that is specifically designed to address the Nature-based solutions implementation and mainstreaming process. Despite these and other credible works, it is appropriate to move forward with a more practical framework that complies with European Commission standards to support the process of developing and delivering nature-based solutions for sustainable urbanisation and building climate resilience. Given the complex mechanisms that typically underlie urbanisation and its effects on the delivery of ecosystem services, the framework should situate nature-based solutions in the appropriate context downstream from the overall cause-and-effect process of urbanisation.

Besides, since ecosystems are self-organising and adapt in response to numerous interactions across many levels of scale the results of management interventions, thus nature-based solutions cannot be predicted with certainty. As a result, a framework that includes in-depth reflection, which is a component of experiential learning, can express the challenges and strategies better for managing uncertainty. Long-term monitoring is also necessary for NBS to be successful. The ability of managers to evaluate the efficacy and outcomes of management interventions and adjust management accordingly is essential for the long-term stability of nature-based solutions. To obtain a wide range of social and environmental advantages, monitoring programmes should be institutionalised inside organisations and stakeholder groups that manage a landscape. Overall, an adaptive management framework is required for nature-based solutions to function well (Brears, 2020; Cohen-Shacham et al., 2019; Kabisch, Korn, Stadler, & Bonn, 2017).

This idea of an adaptive management framework makes it a circular and flexible scheme, making each stage dependent on the others but not necessarily in the same sequence. The four stages are shown in Figure 3. They are 1) challenge identification at the visioning stage; 2) scenario building and intervention stage; 3) monitor and evaluation stage; 4) adapt and adjust stage. Multiple types of engagement and communication are required to reach stakeholders of different power, expertise and interest at each stage. Below the proposed framework is described and each stage is illustrated in some detail as shown in Figure 4.

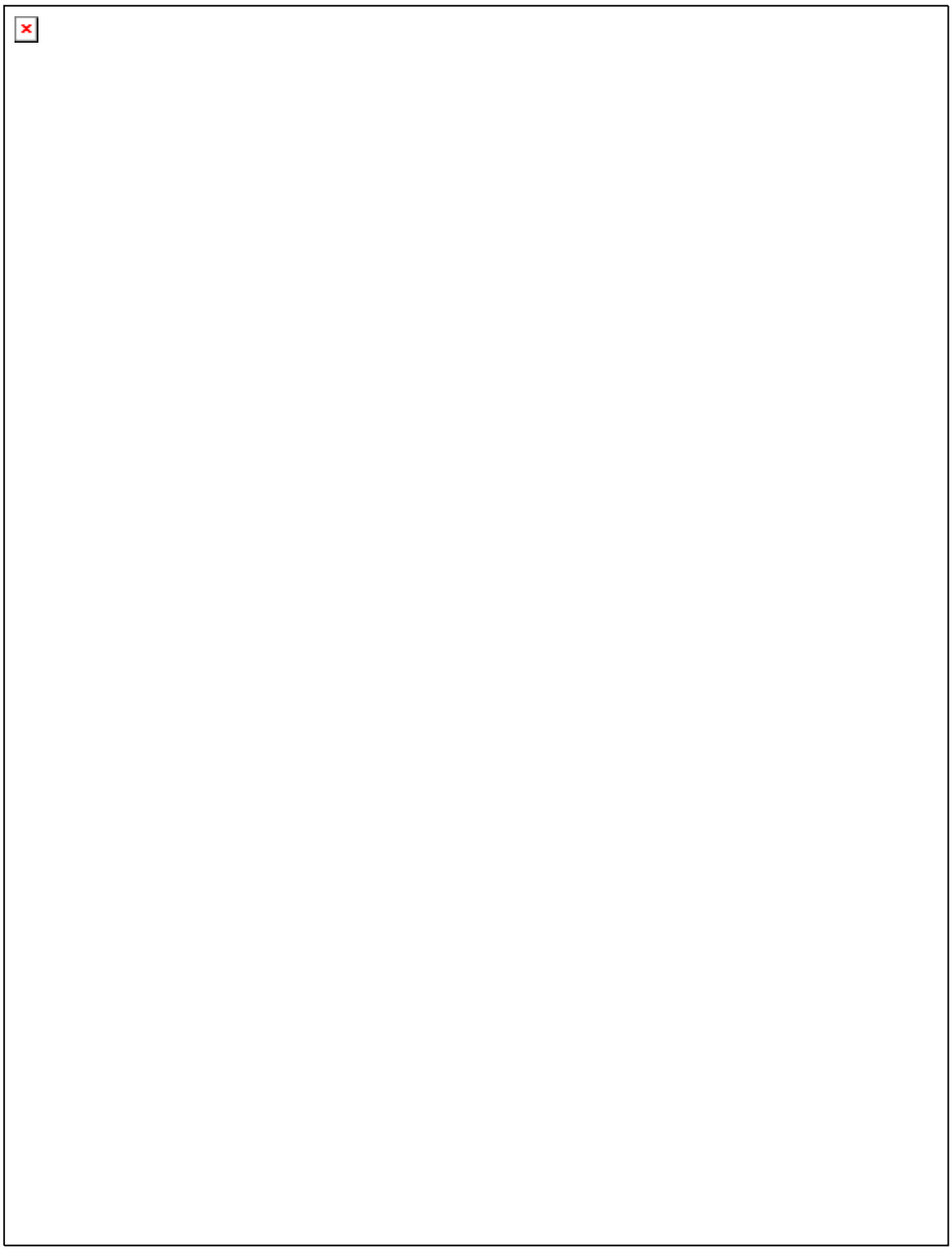

Figure 4: The proposed framework for implementation of Nature-based solutions in Coastal Cities.

6.1 Challenge identification and visioning stage

In many cases, the problems that nature-based solutions must address are multidimensional and complex. After identifying the problem areas, criteria for assessing the relationships between problem dimensions and potential blind spots, or missed opportunities, must be established. Therefore, in this stage, the question to be asked is "What are the project's identified needs and challenge areas, and what criteria will be used to understand problem dynamics?" The process of this stage is done in two steps. The first step is identifying the societal challenge of the coastal area that needs to be addressed setting the objectives of this project. The second step is understanding and assessing the current situation to define the problem dynamics. According to Lafortezza and Sanesi (2019) the European-born DPSIR (Driving Force – Pressure – State – Impact - Response) standardised framework is used to mainstream this step of investigating their effects on the dynamics of urban areas (Gabrielsen & Bosch, 2003). The DPSIR model is an environmental assessment tool

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and one of the most important decision-making tools that have emerged in the last fifteen years to analyse the cause-effect relationships that exist between society and the environment and to support decisions in response to environmental issues (Gregory, Atkins, Burdon, & Elliott, 2013; Spanò, Gentile, Davies, & Lafortezza, 2017). Gaps in ecosystem service delivery/supply, as well as trade-offs between ecosystem services, can be used to complement problem analysis. After identifying the issues and assessing the current situation, the next critical step is to determine the adequate response with which nature-based solutions and alternative grey/hybrid solutions can address them. The multiple benefits that nature-based solutions are providing must be identified and compared to the benefits of alternative green or grey/hybrid solutions.

6.2 Scenario Building and Implementation Stage

During this stage, the urban planner's design and identify a set of concrete actions that will lead to the desired situation according to the urban planning intervention scale. The proposed scenarios include various actions that can be taken to achieve the main objective and sub-objectives identified during the visioning stage. Thus, moving from the 'archetype solution' to concrete ones is implied by this step. Natural, or hybrid solutions can be used as alternatives. They always include a 'doing nothing scenario as a baseline for appreciating the difference brought about by various courses of action. Because nature-based solutions or hybrid solutions are based on ecosystem services, identifying this type of alternative requires matching stakeholders' desires and needs (ecosystem services demand) as developed during the visioning stage with what local ecosystems can deliver (ecosystem service supply). Ecosystems are typically multifunctional, containing a wide range of (potentially interacting) ecosystem services. When a group of services appears together repeatedly in time and/or space, it is referred to as a 'bundle,' (Raudsepp-Hearne, Peterson, & Bennett, 2010) and the positive and negative associations between its services are referred to as synergies and trade-offs (Mouchet et al., 2014).

Given that nature-based solutions imply ecosystem management for societal and environmental benefits, the impact on ecosystem services associations should be considered. If there is a mismatch between ecosystem Service supply and ecosystem services demand, a different option can be chosen, or the objectives can be refined. Climate resilience must be tested after the alternatives have been identified and designed. This enables considering nature-based or traditional investment options over the medium to long term, and not just in terms of the hazard they are designed to address. A mapping of the expected 'performance' of climate-proof alternatives should be carried out as a preliminary step to the quantitative assessment. In fact, nature-based solutions may be competitive with traditional grey interventions only if their multifunctionality is considered. This entails breaking down the expected effects of each alternative in terms of (in)direct environmental, social, and economic benefits and costs, in order to provide a comprehensive basis for assessing and selecting alternatives. Accordingly in this step multi criteria analysis (MCA) is used to select and rank NBS measures because of its ability to integrate and overcome differences between technical and social approaches (Loc, Duyen, Ballatore, Lan, & Das Gupta, 2017). MCA also allows for the evaluation of potential measures using a variety of criteria defined by different units, both quantitative and qualitative (Ruangpan et al., 2021). Based on the results of this qualitative screening, decision-makers can return to the definition of alternatives to refine them. Indeed, as the effects of climate change enter the picture, the effectiveness of an alternative in achieving the predefined objectives and sub-objectives may be jeopardised. As a result of the feedback loop, more climate-resilient options can be designed through an iterative and participatory process.

6.3 Monitoring and evaluating stage

Monitoring involves observing system characteristics after implementation and gathering evidence on how nature-based solutions and measures perform in practice. The disparity between expected and actual outcomes reveals information about the system's response. The interventions should be reviewed and modified to address the challenge or potential new needs (evaluate and adapt). This could lead to several feedback loops over time. To assess the effectiveness and impact of nature-based solutions, information from various monitoring sources and fieldwork is compared to current targets, such as annual targets compared to annual achievements, or long-term targets compared to cumulative annual achievements.

The monitoring and evaluations of s nature-based solutions projects have three major goals: (1) provide information and responses for further advancements and timely project execution, (2) account for expenses

incurred, and (3) fill gaps for effective and successful implementation of future projects. Precise and measurable 'Key Performance Indicators (KPIs)' and 'Key Impact Indicators (KIIs)' are required to monitor the potential effects of implementing nature-based solutions on the specific societal challenge in coastal cities.

6.4 Adapt and adjust stage

The previous phase (evaluation) may also result in a corrective action (adapt) to ensure the measure's long-term effectiveness. This could imply combining nature-based solutions with a more traditional approach, for example. Alternatively, the process could be reversed and new objectives for the system of interest defined. Furthermore, the proposed assessment framework forms part of a larger approach to the implementation of nature-based solutions in coastal cities. As nature-based solutions in coastal cities evolve, they must be managed continuously, and their effectiveness monitored. Therefore, the adapt and adjust stage in adaptive management can help achieve this goal (van Wesenbeeck et al., 2017). This allows for more effective revision and refinement of actions to achieve the desired/expected outcomes (Williams, 2011).

7 DISCUSSION AND CONCLUSION

The growing emphasis on nature-based solutions in policy and research has encouraged efforts to define guiding principles and to design effective assessment frameworks that meet public policy requirements while empirically demonstrating the societal value of 'working with nature.' This framework proposes what reconciles and complements previous efforts while introducing new, complementary elements to support a comprehensive evaluation of nature-based solutions' effectiveness in coastal cities of the Mediterranean Zone. In other words, while the theoretical level is well defined, the potential multiple benefits of the nature-based solutions approach in coastal cities in terms of climate-adaptive and resilient built environment transformation are rarely realised due to a lack of understanding of the scientific knowledge that supports regenerative solutions. A regenerative climate-resilient urban planning that incorporates nature-based solutions has several measurable consequences, including the ability to combine for instance recreation with flood risk management, heritage with urban cooling, health promotion with economic growth and social inclusion.

The reference framework presented in this paper takes an interdisciplinary approach and demonstrates how nature-based solutions can effectively function as downstream responses in urban areas and city regions to meet sustainability goals. The framework's strength lies in its standardised DPSIR structure and applicability, as it allows for the disentanglement of the complex factors and mechanisms underlying the process of climate resilient urbanisation and the consolidation of the close "cause-effect relationship" between ecosystem services and nature-based solutions. In other words, the framework serves as a streamlined support tool for city managers, policymakers, and decision-makers, breaking down complex concepts through a direct application of nature-based solutions for co-developing climate-resilient coastal cities facing urbanisation pressures. Furthermore, this cascading framework efficiently serves the purpose of demonstrating 1) how nature-based solutions work well within ecological processes and human-environment interactions, and 2) that nature-based solutions are to be considered as the proven response to today's urgent climate change issues at both the local and regional scales through its interactive process or loop system.

The current study's next steps will consider its implementation in an existing study area in order to support the inclusion of climate resilience in local urban planning strategies and promote their importance among stakeholders and decision-makers. The author intends to apply the current framework to the study areas in the northwestern Egyptian Mediterranean coast, particularly on one of the new development cities such as Alamein New City, in order to achieve the results envisaged by the framework.

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