NATURE-BASED SOLUTIONS:

CHALLENGE OR OPPORTUNITY?

Nature-based solutions are actions to protect, sustainably manage, and restore natural or modified ecosystems.

The European Dredging Association (EuDA) participated in a Horizon 2020 project sponsored by the European Union. The project named ThinkNature had as objective to promote the application of nature-based solutions (NBS). NBS have obvious advantages but have not been embraced at wider scale. In this article, the authors reflect as to why NBS are not mainstream solutions, why it is necessary to promote the concept and whether there are barriers that hinder wide-scale application. In this article the authors describe how relevant the topic is to the dredging community.

What are nature-based solutions?

The concept of nature-based solutions (NBS) is relatively recent. It has emerged during discussions at the United Nations Framework Convention on Climate Change (UNFCCC) in 2009. This concept has the advantage of encompassing a broad range of diverse approaches and is thus convenient for promotional purposes. Nevertheless, a definition is needed for practical use.

The International Union for Conservation of Nature (IUCN) has proposed a useful definition:
Nature-based solutions are actions to protect, sustainably manage, and restore natural or modified ecosystems. NBS address societal challenges effectively and adaptively, simultaneously providing human well-being and biodiversity benefits.

The IUCN also clarified that:
NBS are designed to address major societal challenges, such as food security, climate change, water security, human health, disaster risk, social and economic development.

It is clear that IUCN considers NBS as a very wide-ranging concept that should play a role in solving humanity's main challenges. In order to make it more operational, the concept needs more focus and further refinement. To this end, the European Commission *(EC, 2015)* refers to nature-based solutions as sustainable responses to specific societal challenges:

- solutions that are inspired and supported by nature,
- which are cost-effective,
- simultaneously provide environmental, social and economic benefits and,
- help build resilience.

Such solutions bring more, and more diverse, nature and natural features and processes into cities, landscapes and seascapes, through locally adapted, resource-efficient and systemic interventions.

Even with this more explicit description, the concept of NBS still remains very broad covering a wide variety of ecological approaches and ecosystem-based disciplines. In other words, NBS can be viewed as an umbrella concept that covers more common terminology such as conservation, restoration, mitigation, adaptation or more familiar approaches such as building with nature, ecological engineering and so forth.

Table 1 illustrates this large scope. It should be noted that there is considerable overlap between the various categories or approaches.

TABLE 1

An overview of possible categories of NBS and examples of each category.

Categories of nature-based approaches	Examples
Ecosystem restoration approaches	Ecological restoration Ecological engineering Forest landscape restoration
Issue-specific ecosystem-related approaches	Ecosystem-based adaptation Ecosystem-based mitigation Climate adaptation services Ecosystem-based disaster risk reduction
Infrastructure-related approaches	Green infrastructure Building with nature Engineering with nature

The ThinkNature project

In view of the large number of possible approaches, the TN project took a pragmatic start by listing good examples. They made an inventory of case studies that are thought to be representative of NBS and compiled them in a data bank OPPLA which is publicly available (https://platform.think-nature.eu).

Next, the project reviewed the conditions for wider application of NBS type projects. This resulted in an overview of barriers and benefits of these NBS projects. While the benefits of nature-based approaches may be apparent, they are not yet well known by the public at large. Moreover, several institutional barriers related to financing, procurement practices and organisational structures slow down wide-scale introduction of innovative solutions, including NBS.

A further step in the analysis considered more specifically the type of problems for which a nature-based solution would be required. The prime examples of such problems are found in the consequences of climate change (temperature, precipitation, drought and sea level rise) and the disasters they may cause. 'Green' projects can form building blocks for climate change adaptation.

In the current OPPLA data base some 80% of the reference cases relate to urban situations. As representatives of the dredging sector participating in the project, the authors pointed out that besides solving urban problems, the NBS concept can be meaningfully applied to broader fields. There is a huge potential for instance to use 'green' or 'blue' civil infrastructure to combat risks of flooding and natural disasters.

The authors proposed a framework as shown in Table 2, which clearly differentiates the various NBS approaches used in urban environments, rural landscapes, river catchments and for coastal protection. Two cases – in Seoul and West Africa – illustrate this.

Via this framework, it becomes evident that the dredging sector can tackle many problems or threats in river and/or coastal environments by implementing NBS. It is therefore important to articulate the major role that dredging and marine contracting can play in this context.

So, why have NBS not been embraced at wider scale? Why is it necessary to promote the concept? Are there barriers that hinder wide-scale application?

The ThinkNature project explored these issues. Hereafter, the article discusses the major aspects that distinguish NBS from more traditional approaches. A more exhaustive coverage of these topics may be found in the ThinkNature Handbook (ThinkNature, 2019).

Wide range of ecosystem benefits

Variability

As explained with Table 2 above, Nature-based Solutions (NBS) necessarily build on natural processes and functions, both of biological and

TABLE 2

Framework for NBS applications.

I. Pressures/issues	II. Drivers/catalysts	III. Relevant ecosystem process	IV. Typical NBS responses
Urban environments Heat islands Pluvial flooding Shortage fresh water Air pollution peaks	Temperature rise Precipitation increase Droughts (Air) Emissions	Air filtration Evaporation Water infiltration Phytoremediation Energy flows Bioretention water	Green roofs Rain gardens Create green spaces Urban forestry Swales for infiltration Room for water retention De-culverting urban streams
Rural landscapes Soil degradation Invasive species Pesticides Poor fauna and flora	Droughts Biodiversity loss Poor agricultural practices	Phytoremediation Water management Bio-diversification Pollination Nutrient cycling	(Re)constructed wetlands Crop diversity modes Restore landscape diversity Re-forestation Water retention Eco-agriculture
River catchments Fluvial flooding Shallow waters Water quality	Precipitation increase Drought periods Chemical pollution	Hydro-morphology Floodplain function Water management Flows (water, sediment) Buffering	Restore floodplains Re-connect oxbows Water retention capacity Flow capacity Natural river banks and riparian zones
Coastal zones Increased erosion Coastal flooding Wave attack Sediment shortage Urbanisation	Sea level increase Storm intensity Wave energy	Sediment transport Energy dissipation Hydrodynamics Bioturbation Carbon cycling	Restore natural sea defences (sandy, mangrove, marsh, etc.) Stimulate natural defences (sediment supply, barriers, etc.) Combinations of soft and hard defences Management strategies

Two Examples

Seoul
Problem/causes: A densely built-up city experiences negative effects such as heat islands (I) during high temperature (II) periods.
Processes and NBS: Providing open space in a city section could be combined with a process of evaporation (III). A river flows through the town, but has been covered since many years (poor smells!). The water quality of the river has improved over the years and there is the possibility to re-open the river and develop river banks inside the city by de-culverting (IV).

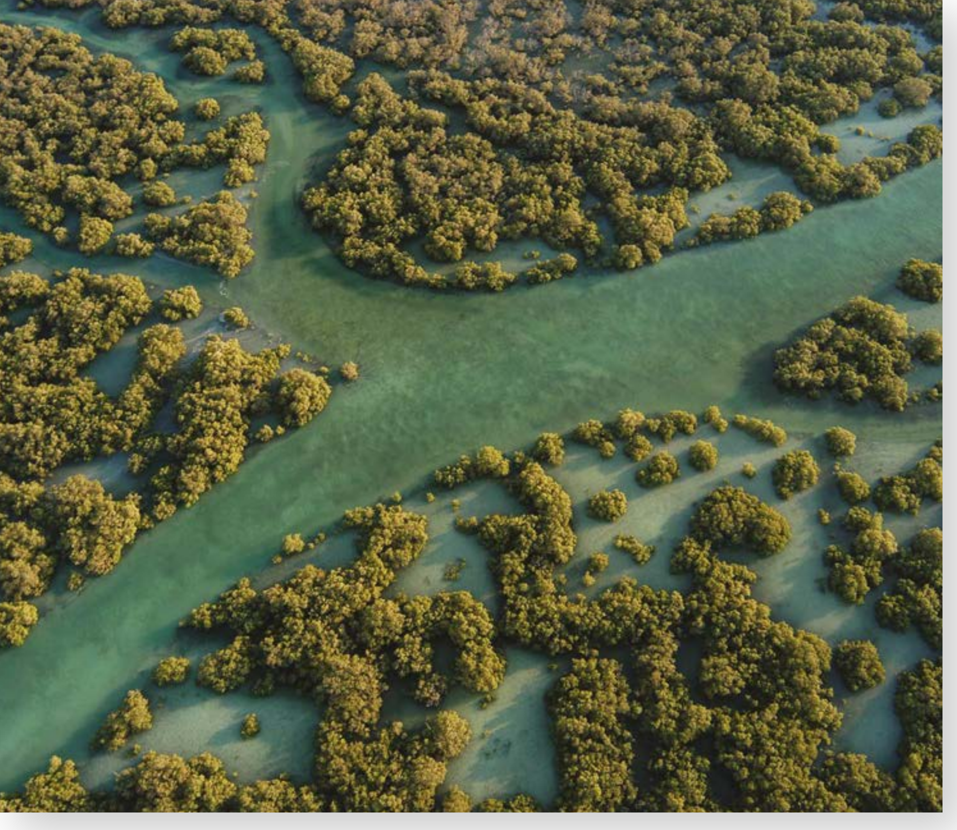
Results: The effect will be to lower the temperature during a hot spell (water temperature lower, evaporation), and by developing the banks as green space there are multiple benefits for nature and for the population. The example of Seoul that can be found in the data base illustrates this solution very well.

Mangroves in West Africa
Problem: In a West African country a long period of drought (II) has caused the death and destruction of a mangrove forest in brackish water causing poor flora (I). The local population has lost a significant source of income (e.g., firewood,, shrimps culture, medicinal plants); also the groundwater is now subject to siltation because the barrier provided by mangrove roots is no longer there.

Processes and NBS: Once the period of drought is over, support to the local population to replant the mangroves for buffering (III) is an effective NBS leading to restoration (IV).

Results: The local economy will be re-established, the local society is stabilised and the benefits of this ecosystem materialise again. Wider ecosystem benefits include also the positive effects for the carbon balance, since mangroves form important carbon sinks.

The local economy will be re-established, the local society is stabilised and the benefits of this ecosystem materialise again.



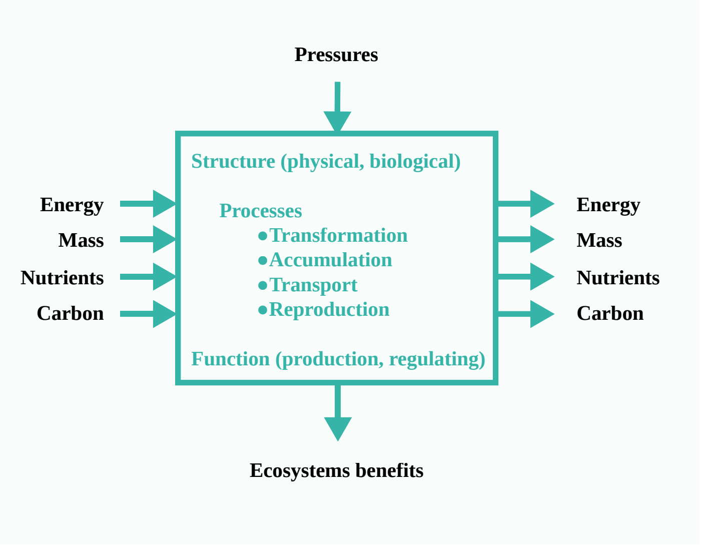


FIGURE 1

Ecosystem schematic.

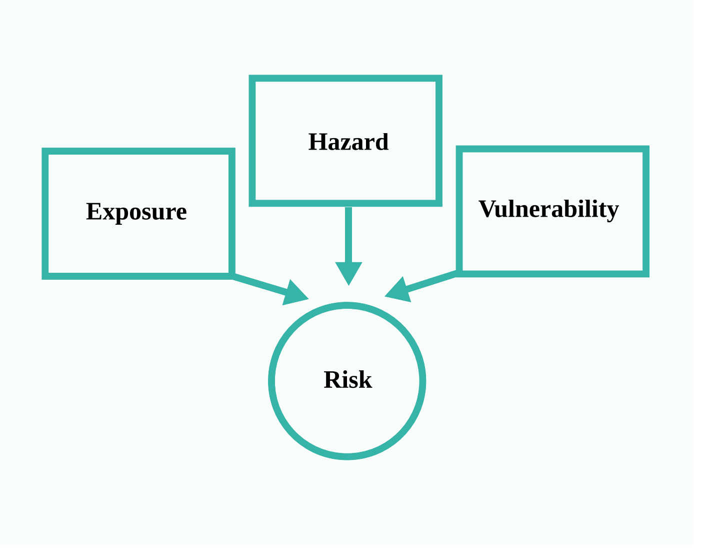


FIGURE 2

Risk illustrated.

of physical nature. This observation points immediately to the first difficulty experienced when implementing NBS: the evolution of natural systems can be influenced by human action to some extent, but there remains always an element of uncertainty and limited predictability. The limits of predictability and knowledge represent the first significant barrier to the acceptance of NBS. Project proposals encounter scepticism, simply because the outcome of the projects cannot be guaranteed in the same manner as for traditional grey infrastructure projects.

Ecosystems as cornerstone

Ecosystems form the building blocks of NBS. The majority of NBS involve the creation or restoration of ecosystems. This category of solutions is commonly referred to as ecosystem-based approaches. It is therefore relevant to recall some propensities of ecosystems.

An ecosystem is defined as a biologically qualified open system formed by a dynamic complex of living organisms within a well-defined boundary where the organisms interact with each other and with their a-biotic environment.

Note the importance of ecosystems as open systems; this implies that energy and mass exchange with the surrounding environment takes place and as a consequence the system can evolve towards higher levels of biodiversity; they usually have the capacity to recover from disturbances (resilience).

Within the ecosystem one can further distinguish several aspects or attributes:

- Ecosystem structure refers to the internal organisation of the ecosystem and the relationship between its various elements (habitats, species populations, etc). It is helpful to differentiate between the a-biotic structure (type of substrate, special habitats) and the biological structure (the interaction between biotic elements and the a-biotic substrate).
- Ecosystem processes are any changes or reactions, physical, chemical or biological, that occur within the system and which influence the flows, storage and transformation of materials and energy. These processes connect also the trophic levels via food chains. Processes include production and reproduction, decomposition and purification.
- Ecosystem functions are the outcome of physical, chemical and biological activities that uphold the stability and biodiversity of the ecosystem. They may be seen as the result of the interaction between structure and processes. Here one distinguishes between production functions (food, raw materials, etc) and the regulating functions (nitrogen, carbon and phosphorus cycling; see Figure 1).

Ecosystem benefits

Healthy functioning ecosystems provide benefits for nature and for mankind. In the Millennium Assessment (2005) these benefits have been called ecosystem services and have been classified as provisioning, regulating, cultural and supporting services, but other classifications are possible. Besides, the terminology 'ecosystem services' has not been uniformly accepted. (R.Gunton, 2017; S.Diaz, 2018). Therefore, in this article the general term 'ecosystem benefits' is used in accordance with the definition of NBS suggested by the European Commission. A distinction is made between environmental, social and economic benefits.

Benefits are by definition 'beneficial', so what is the problem? The main issue with environmental, social and economic benefits is the differences in valuation: not all environmental and social aspects can be quantified, some need qualitative evaluations which cannot always be meaningfully compared with other quantified variables. This may lead to a lack of mutual understanding and endless discussions between stakeholders.

Moreover, ecosystems provide a variety of benefits, but for different categories of beneficiaries or stakeholders (private versus public, local versus generalised, short term versus long term). This may create additional complications for the correct assessment of investment costs and for valuation and allocation of future benefits. This is especially an issue for private investors. More on this under 'Valuation' below.

Risk and Resilience

Many of the problems listed in the first column of Table 2 could result in disastrous consequences. A natural phenomenon is a physical process such as an earthquake, storm, flood and so forth while a natural hazard is the occurrence of a natural phenomenon in or near a populated area. A natural disaster occurs when a natural hazard leads to financial, environmental and/or human losses.

The probability of catastrophes occurring increases as the climate continues to change. For example, the probability of fluvial flooding due to more intense precipitation is increasing. Measures should then be taken in river basins to mitigate the effects of high water. Clearly the consequences of the flooding of a large city are disastrous and can be very costly (in terms of human lives and economic assets). But in order to plan for appropriate measures in the river catchment and to justify investments, it is necessary to get a better handle on the quantification of risks.

Risk

Risk can be seen as the probability to experience serious losses (disaster). This is a concept used by the insurance industry. This risk concept can be further refined as 'the probability that a hazard results in severe consequences'. Or, in a formula: (Risk) = (Probability of hazard) x (Vulnerability of defences) x (Exposure to hazard effects). (see Figure 2).

In fact, disasters occur when hazards meet vulnerability: the resulting loss depends on the vulnerability of the affected population or its incapability to resist the hazard.

In other words, there are three dimensions to risk. While we may have little or no influence on the hazard to occur (flood rains, seismic event, hurricane, etc), humans have increased the frequency of the hazards linked to

FIGURE 3

Hondsbossche Dunes. Photo Ecoshape

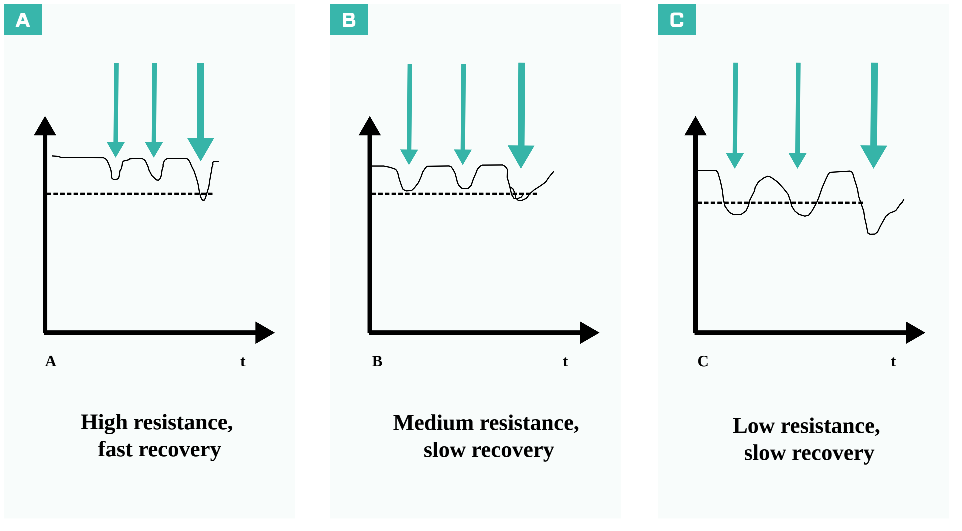


FIGURE 4

A schematic depiction of ecosystem resilience. High resistance with fast recovery (A), medium resistance with slow recovery (B) and low resistance with slow recovery (C).

Coastal protection can form a variety of combinations of soft and hard structures, of grey and green approaches.

climate change. Human actions can also influence the risk by reducing the vulnerability (strengthening defences) and/or by limiting exposure to hazards. Vulnerability is the trickier element of the three. Vulnerability is generally described as 'predisposition for damage and/or loss', but in the context of risk it must be applied strictly to the effectiveness of defences against extreme events.

Example of risk reduction in the case of river flooding:

- one can reduce vulnerability by building hard or soft flood defences, restoring flood plains, create more buffer capacity;
- one can reduce exposure by taking specific measures such as construction of houses in the floodplain on elevated piles to avoid damage.

From this example it is evident that NBS can play a significant role in reducing vulnerability and thus risk. In river basins many nature-based measures can be taken upstream in order to reduce the flood levels downstream near a city. Along coastlines threatened by severe storms or extreme tides, natural defences can be strengthened or enhanced, again in view of reducing vulnerability and thus overall risk. But nature-based solutions have no direct results for exposure. A thorough discussion of these issues is provided in a

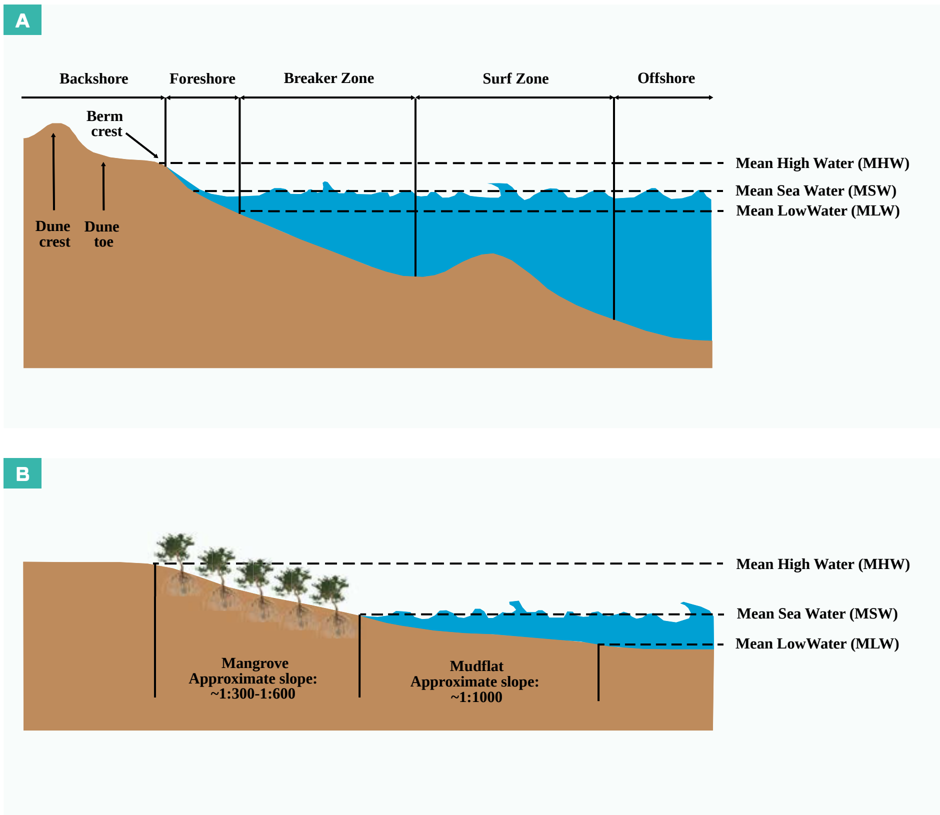


FIGURE 5

Natural coastal defence systems in a sandy beach system (A) and mangrove system (B)..

TABLE 3

Coastal defences possible options.

	Hard (grey)	Natural defences	Nature-based
Primary defence	Structures Seawalls Dykes Revetments Rock walls Barriers	Dunes Mangroves Saltmarsh Cliffs Rocks	Dune reconstruction Re-growing mangroves Development saltmarsh
Supporting structure	Breakwater Groynes Artificial reefs Rock structures	Sandbanks Barrier islands Sandy beaches Pebble beach Mangroves Wetlands Reefs/Coral reef Seagrass	Beach nourishment Sand Engine Building barrier islands Hardening sandbanks Intro bio-engineers Re-grow coral reefs Seagrass beds/kelp dvpt. Eco-friendly substrate

publication by the IPCC (International Panel on Climate Change), (IPCC, 2012).

An excellent example of reducing vulnerability by natural means is provided by the Dutch sea defence ‘Hondsbossche Dunes’. The existing dike needed strengthening because of sea level rise, which forms a potential hazard. Rather than building more grey infrastructure (higher dike), the natural dynamics that existed locally centuries ago were restored by providing sand from the sea. The sand was used to rebuild dunes and nourish the foreshore. In this manner the natural dynamics of a sandy coastal defence system were restored and the vulnerability is reduced.

Resilience

When grey infrastructure is built to protect against extreme events (e.g., flooding), there are basically two outcomes: the structure holds or it fails. Nature-based features are different, they may resist the attack or they may degrade, but even in case of severe disturbance there is the potential to protect partly or to recover from the damage. This characteristic is called resilience.

Resilience of ecosystem functions is the capacity for these functions to resist and recover from disturbances. Ecosystems are dynamic systems that tend to return to an equilibrium state following events that upset its equilibrium. This propensity has its limits; when the disturbance as a consequence of hazardous events is too important, tipping points may be reached that result in the system functioning at a different (but less productive) equilibrium level.

The opposite of resilience is the vulnerability of the system. For NBS as the defence against extreme events, one would hope to find ecosystems with high resistance and reasonable recovery rates. The features of ecosystems that enhance its resilience include a high degree of biodiversity, a rich variety in species, functional redundancy, and connectivity to nearby ecosystems (Oliver, 2015, Linkov, 2014, Ulanowicz, 1997). For ecosystems where physical processes are dominant, such as for the coastal system of sandbanks or barrier islands, beaches and dunes-, the interaction between the a-biotic elements of the system is also an important parameter. Figure 4 illustrates the concept of resilience.

TABLE 4

Mangrove benefits.

Planting/re-developing Coastal Mangrove Forest for coastal protection	Expected ecosystem benefits (mainly long term)
Environmental/ecologic benefits	Erosion protection, barrier against saline intrusion, enhanced biodiversity, carbon sequestration, water purification
Social benefits	Support local community (‘commons’), social cohesion, (bird watching, tourism)
Economic benefits	Fish nursery, seafood production, honey production, construction material, substances for medicines, reduced flooding risk

Nature-based solutions in coastal defence

Coastal protection can form a variety of combinations of soft and hard structures, of grey and green approaches. In practice one will often encounter such hybrid solutions. Since these hybrid approaches include nature-based features, they qualify as NBS, even if not all the features are eco-engineered.
For natural systems the coastal defence function is primarily based on the healthy functioning of the a-biotic elements in the ecosystem and supported by the biotic processes. The functional challenges are: how to deal with the incoming (wave) energy, with erosion phenomena and with the threat of flooding from high sea levels or extreme events. One should distinguish between the primary defence function or structure that protects against floods and the supporting structures that deal more specifically with wave energy and erosion. In many cases there are two different supporting structures. Well known examples in nature are provided by a system of dunes, sandy beaches and barrier islands, or by the combinations of mangroves, wetlands and muddy foreshore. (see Figure 5).

The following categories are distinguished:

- Natural and nature-based defences;
- Hybrid systems. The hybrid systems respect the dynamics of natural processes and resist the pressures on the coastline by combinations of green and grey elements;
- Hard engineered structures.

These different classes of systems and structures can be allocated to the primary and the supporting structures to form the coastal defence. The author’s observations in this section have benefited from the paper by (Van der Nat, 2016).

The possibilities are listed more explicitly in Table 3.

While the difference between natural defences and hard engineered structures is clear, for hybrid systems some clarification is necessary. Both combinations of grey primary defence plus NBS supporting structures and NBS primary defence plus grey supporting structures form hybrid solutions. In both these categories NBS are part of the defences and the overall system solution should qualify as nature-based.

Valuation

For NBS to be considered as realistic candidates for projects, one needs to leave the comfort zone of business-as-usual. The costs of an investment in NBS will have to be justified, but in non-traditional manners. In this section several of the issues at stake are highlighted.

The provision of nature- based sustainable infrastructure requires business models that involve long-term exchange-value creation. A business case must be developed that is both comprehensive and convincing.

For traditional grey infrastructure a cost-benefit analysis (CBA) is developed at this stage which considers mainly the upfront investment costs. For the case of NBS, there are other important factors that need to be taken into account:

- firstly, total life-cycle costs, including the build-operate-maintain-decommission phases, must be assessed; while upfront investment for NBS projects may be higher than for traditional infrastructure, the maintenance costs over the life cycle are likely to be lower;
- as referred to above, NBS life cycle evolution is not predictable in the same way as for grey infrastructure; there remain elements of uncertainty in predicting the dynamics of the project over time. In a cost-benefit context this means a negative evaluation for lack of guarantees;
- the total suite of expected benefits must be valued and these benefits are typically much broader than for the traditional case; when ecosystems are at the heart of the NBS, they will bring a range of benefits that can conveniently be split up into environmental, social and economic benefits; (see separate Box to appreciate the wide range of benefits associated with replanting coastal mangroves);
- with regard to direct economic benefits the valuation should not be an issue, as they are calculated and expressed in monetary value; there may also be long term economic benefits that will materialise only over time; there is uncertainty in estimating and quantifying the latter, and then there is the question if and how expected benefits should be discounted;
- for expected social benefits (cohesion of society, room for recreation, aesthetic enjoyment, etc) the question is: how should these be valued? Shadow pricing is hardly a credible proposition and, in any case, does not capture the real added value for society; nevertheless, they must somehow be accounted for in the business case;
- similarly, for environmental benefits (carbon capture, contribution to biodiversity, air purification,etc) shadow pricing will likely lead to disagreements ('What is the cost of 1 tonne of CO_2?') and thus uncertainty for the business case; estimating environmental benefits is important, but the valuation in monetary terms is questionable: it provides little indication on the quality improvement of the environment and the positive impact on society;
- as mentioned already, a further complication is that many of the benefits may not be of interest to the investor, but accrue somehow to the local population or neighbourhood; should third parties be invited to become partners in the NBS project, to share some of the risks and to co-invest in exchange of their share of social or environmental benefits?
- for those NBS projects playing a critical role in reducing the risks of extreme events (fluvial flooding, coastal threats, etc), the vulnerability of the landscape needs to be quantified somehow, in order to develop an estimate of reduced vulnerability due to and avoided damage costs thanks to the project; this needs to be assessed as it should translate in lower insurance costs.

Through a number of workshops and conferences, The ThinkNature project led a reflection on these issues, but this has not yet provided final answers. It should nevertheless be pointed out that one possible approach is to compare the three alternative scenarios: NBS, grey infra or 'do nothing'. On that basis the advantages of NBS can be shown, even if no complete monetary valuation can be made.

One thing is clear: the classic cost-benefit analysis cannot be applied as such to NBS. New business models, other governance models and different decision-making rules are required to support the development, and the valuation of NBS projects.

It may also be apparent that large scale NBS projects lend themselves better to financing from public sources than by private investors. Nevertheless, even in the public sector there are fundamental barriers. There is a long tradition in public procurement to award projects to the bidder that offers the lowest price for the initial construction work (building phase). This model is not compatible with the characteristics of NBS projects.

Can NBS compete?

During the EuDA annual conference in November 2019, Mrs Oshana Perera from the International Institute for Sustainable Development (IISD) welcomed the important role that nature-based solutions can play in sustainable infrastructure development. She challenged the audience to mainstream NBS and cross the 'valley of death' to make NBS a viable alternative in the infrastructure market. In her experience the preconditions are that NBS have to meet the criteria of:

- verifiability: demonstrate robust track records (monitoring performance over time, achieving design criteria);
- predictability: (sufficiently) predictable in their performance;
- comparability: be functionally comparable under varying conditions (e.g., geo-zones).

The concrete suggestion to the contracting industry was that the time has come to move beyond the pilot stage and propose 'a catalogue of NBS products'. But can these criteria be satisfied?
Important work has already been done by the EcoShape foundation. The NBS pilots realised under the EcoShape platform have been closely monitored and their performance compared to predictions or theoretical modelling. The evolution of other pilots is similarly being followed with detailed monitoring campaigns such as the US Army Corps of Engineers' programme Engineering with Nature.

The NBS pilots realised under the EcoShape platform have been closely monitored and their performance compared to predictions or theoretical modelling.

The criteria of robust performance and reasonable predictability appear to be within reach.
But there remain other issues that distinguish NBS from grey infrastructure in a fundamental manner:

- as remarked, evolution in nature is never entirely predictable and performance cannot be guaranteed in the same manner as for grey infrastructure. Some form of adaptive management is necessary;
- NBS will have a degree of vulnerability under extreme events. This must be quantified to some extent and the outcome influences the predictability;
- the third test of comparable performance under varying conditions may be too much to ask.
- Indeed, NBS need to be functional in different climate zones under widely different conditions, and the specific applications may therefore be different. Mangrove development along coastal zones is realisable in many areas in tropical and semi-tropical zones, but in temperate climate zones similar defensive functions can be realised only by other NBS (e.g., seagrass beds, bio-engineering on sandbanks, etc).

Finally, while there are natural solutions that function as alternatives to grey infrastructure (for ex. constructed wetland for water purification), in other cases NBS will function in tandem with grey solutions and form hybrid systems. In these cases, the choices are not between green and grey, but it becomes a matter of optimising design alternatives.

We conclude this section by observing that a catalogue of 'off-the-shelf' nature-based solutions is not realistic, because there are too many variables involved (climate zone, type of hazard, existing features, hybrid systems, etc). Nevertheless, a variety of nature-based approaches is available for application in river catchments and for coastal defences.

Conclusions

Nature-based solutions represent valid options for integration into coastal and flood defences. They can be applied as purely nature-based or combined with grey infrastructure to form hybrid systems. The evolution of nature-based features over time implies an element of uncertainty. Traditional public procurement methods, decision-making and governance as well as the traditional cost-benefit assessment models are not suitable for nature-based solutions and projects. The business case for nature-based solutions needs to account for a range of specific issues, including life-cycle costs and benefits estimates, assessment of vulnerability, allocation of multiple benefits, different types of guarantees.

Nature-based solutions represent valid options for integration into coastal and flood defences.

Summary

The concept of nature-based solutions (NBS) is relatively recent. It has emerged during discussions at the United Nations Framework Convention on Climate Change (UNFCCC) in 2009. This concept has the advantage of encompassing a broad range of diverse approaches and is thus convenient for promotional purposes. A definition is needed for practical use.

The European Dredging Association (EuDA) participated in a Horizon 2020 project sponsored by the European Union. The project named ThinkNature had as objective to promote the application of NBS. NBS have obvious advantages but have not been embraced at wider scale. In this article, the authors reflect as to why NBS are not mainstream solutions, why it is necessary to promote the concept and whether there are barriers that hinder wide-scale application. In this article the authors describe how relevant the topic is to the dredging community.

REFERENCES

EC (European Commission), Directorate-General for Research and Innovation. (2015)
'Towards an EU research and innovation policy agenda for nature-based solutions & re-naturing cities.'

ThinkNature (2019)
Somarakis, G., Stagakis, S., & Chrysoulakis, N. (Eds.)- 'Nature-Based Solutions Handbook' (https://platform.think-nature.eu/system/files/thinknature_handbook_final_print_0.pdf)

S. Diaz et al. (2018)
'Assessing nature's contributions to people' – Science vol 359, issue 6373.

R.M. Gunton et al. (2017)
'Beyond Ecosystem Services: Valuing the Invaluable' – Trends in Ecology and Evolution, Vol 32, No.4.

IPCC (2012)
C.B. Field, V. Barros, T.F. Stocker, D. Qin, D.J. Dokken, K.L. Ebi, M.D. Mastrandrea, K.J. Mach, G.-K. Plattner, S.K. Allen, M. Tignor, and P.M. Midgley (Eds.). Managing the Risks of Extreme Events and Disasters to Advance Climate Change Adaptation. A Special Report of Working Groups I and II of the Intergovernmental Panel on Climate Change'. Cambridge University Press, Cambridge, UK and New York, NY, USA, 594 pp.

I. Linkov, T. Bridges, F. Creutzig, J. Decker, C. Fox-Lent, W. Kröger, T. Thiel-Clemen (2014)
'Changing the resilience paradigm.' Nature Climate Change, vol. 4, issue 6, p.407-409.

T.H. Oliver et al. (2015)
'Biodiversity and Resilience of Ecosystem Functions' – Trends in Ecology & Evolution, Vol.30, No.11.

R.E. Ulanowicz (1997)
'Ecology, the Ascendent Perspective' – Columbia University Press, New York.

A. van der Nat, P. Vellinga, R. Leemans, E. van Slobbe (2016)
'Ranking coastal flood protection designs from engineered to nature-based.' – Ecological Engineering 87. p. 80-90.

The evolution of nature-based features over time implies an element of uncertainty.

Frederik Mink

Frederik is a Senior Consultant with degrees in engineering and business administration. He has a thorough knowledge of European Union environmental and marine legislation and is familiar with environmental challenges faced by the maritime, marine and dredging sector. He has a particular interest in natural coastal defences and is advisor to the European dredging industry.

Prior to becoming an independent consultant, Frederik had ten years of hands-on experience in European Affairs as secretary-general of the European Dredging Association and worked for more than 20 years in the energy field, notably in the nuclear industry.

Paris Sansoglou

Paris holds a degree of Commercial Engineer from the Solvay Business School (Brussels), complemented with degrees in Environmental Studies (ULB, Brussels), Business Informatics (VUB, Brussels) and Financial Analysis (CIAF, Brussels) and is a member of the European and the Belgian Associations of Financial Analysts (ABAFBVFA). He has worked at the European Commission (Eurostat) and ran the secretariat of the European Technology Platform WATERBORNE. He was also involved with the trade association representing European manufacturers of synthetic fibres and the Community of European Shipyards' Associations (CESA), before joining the European Dredging Association (EuDA) as Secretary General in April 2009. He is the co-author of two EuDA papers, presented to WODCON XX and XXI, on Blue Carbon (in the context of carbon management strategies for dredging projects). Paris participated in the project ThinkNature where he provided the input and views of the dredging industry on Nature-based Solutions.