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APPLYING NATURE - BASED SOLUTIONS IN MODERN WORLD

Abstract
Humanity and modern society increasingly face a vast array of environmental challenges, including climate change, food and water security, natural disasters and biodiversity loss. Nature - based solutions (NbS) are an effective mechanism to address these challenges through development and implementation of processes, supported by nature and achieved producing long term societal, environmental and economic benefits. NbS can provide an integrated approach and serve as a powerful tool to address climate change and biodiversity loss, while supporting sustainable development.

Keywords: nature - based solutions, climate change, coastal recovery, resilience, climate adaptation, benefits, co - benefits

Introduction

In accordance with the commonly popular 'polluter pays' principle, when assessing the level of significance of the pollution of soil and groundwater caused by the operator, the trigger level for the "Obligation to return the site to the state described in the baseline report", operators should take into account permit conditions that have applied over the lifetime of the activity concerned, the pollution prevention measures adopted for the installation, and the relative increase in pollution compared to the contamination load identified in the baseline report [10].

Best Available Techniques (BAT) form a basis for a concept applied in practice in many countries. BAT are economically feasible techniques used to reduce industrial emissions (including greenhouse gases). BAT consider (inter alia) prevention or minimization of water status deterioration, air and soil pollution as well as reduction of any related adverse effects on the environment and human health, including closure and after - closure phase [10, 17]. Restoration of ecosystem services, design and implementation of nature - based solutions are used to return the industrial sites site to the state close to that described in the baseline report, or to the new state with the functionality appreciated by the society. The NbS concept is increasing becoming more popular option for searching for options which could be used to create more sustainable development of cities and rural areas. Nature - based solutions could be an option to address societal challenges, providing benefits for both human well - being and biodiversity [21].

Measures to address current concerns can be ranged into three main categories, i.e. 'grey', 'green' and 'soft' measures.

– This paper refers to traditional 'grey' measures as technological and engineering solutions to improve adaptation of territory, infrastructures and people.

– 'Green' measures are the restoration of ecosystems, various types of ecosystem - based solutions such as nature - based solutions and are based on the ecosystem approach reducing impact, directly or indirectly on the existing natural environment.

– 'Soft' measures usually refer to policy, legal, social, management and financial measures that can alter behaviour and styles of governance, contributing to the improvement of existing conditions, reduce risks from natural hazards and mitigate climate changes.

1. Nature - Based Solutions

1.1. Definition, Principles and Criteria for Good Nature - Based Solutions

Nature - Based Solutions have been defined by the International Union for Conservation of Nature (IUCN) in 2016 as "Actions to protect, sustainably manage and restore natural or modified ecosystems, which address societal challenges effectively and adaptively, while simultaneously providing human well - being and biodiversity benefits" [13]. In 2021 the following additional wording were added: "Nature - based solutions must therefore benefit biodiversity and support the delivery of a range of ecosystem services" [12].

NbS have been defined and used in different ways, although many organisations and public bodies prefer to use the IUCN definition. Regardless of the definition, NbS could be considered as umbrella concept uniting a range of ecosystem - related definitions and approaches, all of which are aimed at addressing a broad variety of societal challenges. The IUCN's definition of NbS has been used to define 8 principles to help to build a common language and understanding [13]:

Principle 1: NbS embrace nature conservation norms (and principles)

Principle 2: NbS can be implemented alone or in an integrated manner with other solutions to societal challenges (e.g., technological and engineering solutions)

Principle 3: NbS are determined by site - specific natural and cultural contexts that include traditional, local and scientific knowledge

Principle 4: NbS produce societal benefits in a fair and equitable way in a manner that promotes transparency and broad participation

Principle 5: NbS maintain biological and cultural diversity and the ability of ecosystems to evolve over time

Principle 6: NbS are applied at a landscape scale

Principle 7: NbS recognise and address the trade - offs between the production of a few immediate economic benefits for development, and future options for the production of the full range of ecosystems services

Principle 8: NbS are an integral part of the overall design of policies, and measures or actions, to address a specific challenge.

Various bodies, including IUCN and OECD have made improvements to the NbS concept and terms as well as to develop global NbS standards. In 2020, IUCN developed and released the Global Standard on Nature - based Solutions to ensure that NbS will be able to reach their potential. These standards could be used by governmental organisation, public bodies, businesses, investors, communities and non - governmental organisations (NGOs).

The Global Standard on NbS (Standard) is a user - friendly framework for the verification, design and scaling up of NbS and consists of 8 key criteria [9] and 28 indicators which could provide a valuable support to various users while assessing, identifying and enabling design of NbS:

Criterion 1: NbS effectively address societal challenges

Criterion 2: Design of NbS is informed by scale

Criterion 3: NbS result in a net gain to biodiversity and ecosystem integrity

Criterion 4: NbS are economically viable

Criterion 5: NbS are based on inclusive, transparent and empowering governance processes

Criterion 6: NbS equitably balance trade - offs between achievement of their primary goal(s) and the continued provision of multiple benefits

Criterion 7: NbS are managed adaptively, based on evidence, and

Criterion 8: NbS are sustainable and mainstreamed within an appropriate jurisdictional context.

1.2. Advantages and Disadvantages of Nature - Based Solutions

It is the authors' opinion that the principles and aims of NbS can, at times appear vague and unclear due to their broad framing, but their benefits and potential co - benefits are not in dispute. However, the NbS being a relatively new approach is still being under scrutinised, subjected to practical testing and is yet evolving. Benefits and challenges of NbS are presented in Table 1.

Table 1 – Benefits and challenges of Nature - based Solutions

Advantages of Nature - Based Solutions	Disadvantages of Nature - Based Solutions
NbS can have lower costs compared to costs related to implementation of infrastructure alternatives	NbS can be slow to demonstrate adaptation or co - benefits
NbS can be flexible, specific and / or can address multiple climate challenges	It's hard to demonstrate cost effectiveness (benefit - cost ratios), and intentions (or commitments to NbS) have yet to fully translate into measurable, evidence - based targets for NbS and action on the ground
NbS can provide multiple co - benefits such as better water quality, improved flood protection, improved health,	NbS tend to be very context specific making effectiveness difficult to measure as well as to replicate the experience received

Advantages of Nature - Based Solutions	Disadvantages of Nature - Based Solutions
cultural benefits, biodiversity conservation, biodiversity loss etc.	elsewhere; they may be climate - sensitive
	NbS remain undercapitalised in comparison to conventional infrastructure activities
	There are challenges and uncertainties associated with their dynamic behaviour
	Many of the benefits are non - monetary and hard to measure

Source: [15] with additions made by authors

Nature - based solutions should not be over - simplified and developers shall not be unrealistic about potential impacts and benefits of such NbS. They should be viewed both as an opportunity and as a challenge as they require (i) strong understanding of social and environmental processes, (ii) a variety of stakeholders to be engaged, and (iii) a comprehensive set of societal issues to be included, assessed, integrated and managed through the implementation process. A holistic approach to NbS design, implementation and assessment, especially in urban areas is paramount [1].

1.3. Barriers to Scaling up Nature - based Solutions

Nature - based Solutions are increasingly gaining popularity and becoming widespread around the world and are contributing to tackling a variety of societal and environmental concerns. As a result, the main challenge is moving from demonstration projects to a scaling up around the world. Many acknowledge that there are certain barriers to scaling up nature - based solutions. The key potential barriers to a widespread uptake, implementation and scaling up of NbS include but are not limited to the following:

- limited number of, or lack of standard procedures to assess, deliver, verify and report on the effectiveness of NbS;
- requirement for new protocols for implementation and maintenance, as a lack of awareness / understanding of NbS approaches and benefits which they can bring, especially in tackling climate - induced concerns;
- limited availability of knowledge and evidence to help make the business case for their use (especially against conventional infrastructure alternatives);
- lack of investments in NbS due to absence of a well - recognised unified economic assessment methodology;
- many benefits from NbS are non - monetary and are difficult to evaluate;
- lack of consolidated studies and 'lessons learnt' from the existing and completed NbS;
- inflexible and highly sectoralised policy, regulatory environments, existing direct and indirect subsidies and governance challenges, continue to favour grey, engineered solutions; technical challenges and gaps in capacity that impede wider implementation [15].

Promoting NbS as priority measures and setting ambitious but realistic targets for their scaling up requires a preliminary investigation different NbS types and of the benefits that can be expected from their full - scale implementation [18].

1.4. The Benefits and Co - Benefits of Nature - Based Solutions

Nature - based solutions should benefit nature and biodiversity (e.g. increased biodiversity) as well as to support the delivery of a range of ecosystem services (i.e. reduced risk and increased resilience) through usage of nature's own resources, for example clean air, water and soil, to tackle environmental challenges. If well designed, properly and robustly implemented, NbS can deliver multiple environmental, economic and societal benefits. Such solutions are vital and urgently needed to address numerous global challenges providing parallel benefits for society and the planet.

As adaptation actions the majority of nature - based solutions are cost - effective offering multiple benefits, often referred to as **'triple dividend'** [2], namely:

– **Avoided losses** from disaster reduction measures (for example, early warning systems, resilient infrastructure) which could protect communities and infrastructure in the event of a disaster (i.e. floods, storms, and heatwaves) with opportunities to save countries billions of dollars each year.

– **Economic benefits** expressed in (i) lowering financial costs and more appealing investments in regions, cities and industries, (ii) improved productivity of people and resources and boosts incomes (for example, immediate jobs restoring), (iii) long - term economic growth associated with increasing food and water security, business productivity, innovative technologies and tourism and recreation value.

– **Social and environmental benefits** (or non - market benefits) which are often hard to quantify but extremely important. Benefits could include the reduction in the risk of flooding, increase in biodiversity and improved air and water quality and associated improvements in human health; Further actions can protect natural habitats important for local businesses and mitigate climate change.

However, it is recognised that due to their multifunctionality, any NbS is likely to have co - benefits in other challenge areas and to benefit biodiversity [14]. In this context, term 'co - benefits' means the various benefits or advantages that can be provided by a NbS simultaneously over a certain period or that come from a project beyond its primary aim.

Co - benefits can be derived from NbS addressing societal issues such as water security, food security, human health, well - being and social cohesion, livelihoods, disaster risk - reduction, environmental degradation and biodiversity loss, and climate change mitigation and adaptation [15]. It is important to analyse any potential co - benefits and include them when designing an NbS in order to maximise their effects.

Potentially examples of the co - benefits of NbS could include:

– The restoration and management of wetlands could not only boost fish stocks and widely improve the number of fish, bird and animal variety but additionally can lead to a reduced risk of flooding, improvements to local livelihoods and provide opportunities to develop tourism and recreation.

– Activities aimed at forests conservation not only supporting food security but contribute to climate change adaptation, biodiversity and an improved local economy.

– For water management projects, co - benefits could include: (i) urban biodiversity; (ii) improvements to the urban environment, living conditions and quality of life; (iii) reducing the urban heat island effect through the cooling effect of evapotranspiration [21].

– Indirect economic co - benefits could include increasing real estate values and tax income for local governments.

– Development of green infrastructure in cities and urban environments (e.g., green walls, roof gardens, street trees, etc.) contributes to air quality improvement, reduced stormwater runoff, improving quality of life for local residents and communities.

– NbS or green solutions may produce lower emissions compared to grey solutions that aim at the same goals which will be beneficial with regards to climate mitigation measures.

These multiple benefits for climate change adaptation, mitigation, biodiversity, health, the economy and supporting a fair and resilient economic recovery from the COVID - 19 crisis (with significant potential for creating green jobs) are to be welcomed and studied in more details.

2. Nature - Based Solutions in Action: International Experience

Despite their obvious benefits, at present NbS have limited uptake around the world. Most known NbS focus on restoring degraded and threatened ecosystems (e.g., wetlands, highlands, flood risks, etc.) with a few focused on NbSs within urban environments at scale (e.g., Garden City and Sustainable Urban Drainage initiatives) [6].

A selection of case studies is given below to demonstrate potential for NbS implementation. Most of these solutions provide multiple co - benefits while generating limited or no negative impacts and they could be used as stand - alone options or in combination with traditional 'grey' measures. The examples show NbS in action in a wide range of contexts worldwide and; cases are grouped by areas in which NbS could be utilised in order to tackle various aspects of climate change adaptation and resilience as well as improvement of natural environment and enhancing economic and social development.

2.1. Case Studies – Coastal - Based Solutions

Coastal ecosystems (coral and shellfish reefs, seagrass meadows, mangrove forests and salt marshes, etc.) act as physical barriers to waves, reducing the impact they have on the shore. Restoration and realignment of the coastal ecosystems reduce coastal erosion and flooding as well as to re - establish their natural functions. On a worldwide scale, about 30 % of the flood - exposed low - lying coastal plain benefits from nature - based storm surge mitigation (e.g. the Pearl River, Yangtze, Mekong, Elbe) [23]. Coastal wetland restoration is therefore considered a critical component of coastal protection.

NbS can be used to support biodiversity and local fisheries. It sequesters carbon and serves as a good tool providing significant potential co - benefits for the local economy and natural environment.

Table 2 – Coastal - based solutions

Case study	Brief description	Key benefits and co - benefits achieved
Coastal managed realignment, Medmerry, West Sussex coast, UK, 2009 - 2013	The project involved building new sea defences inland from the coast and creation of a new 'intertidal' area. This new intertidal area is exposed at low tide and covered by the sea during high tide. As part of the project seven kilometres of new flood banks were constructed between the settlements of Selsey and Bracklesham Bay in the UK. Upon completion, the bank allowed inflow of sea water inland and creation of 184 ha of intertidal habitats.	Climate change mitigation and adaptation through creation of the intertidal habitat, including saltmarsh acting as a blue carbon store
Coastal wetland restoration, New Orleans, Louisiana, USA, 2019 – present	This project is aimed at establishing the flow of sediment to restore the natural processes which initially created the Mississippi Delta. The 4,420 acres of wetlands adjacent to New Orleans is an essential barrier in protecting the city from coastal flooding, serving as a wetland buffer and absorbing wave attenuation. Many navigation channels, flood walls and oil / gas canals destroyed wetland and posed significant impact on coastal protection functions creating land loss and penetration of salt waters inland. In addition, ecosystem services were reducing. This project is crucial as it will (i) ensure flood protection, (ii) enhance community resilience for the Greater New Orleans area, and (iii) provide estuarine habitat for fish and wildlife. The project will cost an estimated $50 mln to implement.	– Increased coastal protection from floods, waves and storms – Development and maintenance of healthy and diverse fish habitats and restoration of ecosystems – Reduce land loss, and – Increased resilience of the existing ecosystems and wide range benefits for tourism and fisheries.
Seagrass restoration in the UK, 2021 – present	In the UK within last decades seagrass meadows have been highly degraded with up to 92 % of historical cover lost. The Sea grass restoration project launched in 2021 marked the first ever major seagrass restoration project in England. At a site in Plymouth Sound 18,200 biodegradable	– Increased resilience of the existing ecosystems – Provision of a wide range of benefits for other sectors, such as tourism and

Case study	Brief description	Key benefits and co - benefits achieved
	bags of seeds and seedlings have been laid on the seabed which used to be rich in seaweeds. Local people and businesses were highly involved in the process. Volunteers actively participated in placing seeds and seedlings in bags. Public awareness campaigns were organised to ensure that local communities understood the importance of the project and activities associated with its implementation. The project, co - ordinated by the Ocean Conservation Trust aims to restore eight hectares of seagrass over four years. The new seagrass meadow should become a home for invertebrates and fish, also helping to stabilise the sediment and burying carbon in the seabed.	fisheries, and – Provision of the coastal protection.

Source: developed by authors using [16, 23]

2.2. Case studies – Wetland Restoration and Reconnection

Wetlands are highly important for biodiversity – about 40 % of the world's plants and animals are dependent on them and they are part of a natural infrastructure. They are also effective carbon sinks and provide livelihoods for millions of people. The restoration of wetlands and reconnection of floodplains can buffer floods, maintain water flow and improve water quality, provide storage to reduce flood peaks, increase resided time promote infiltration and increase flow during dry season, promote and restore biodiversity and enable the exchange of nutrients and sediment flows (Table 3).

Table 3 – Wetland restoration and connection

Case study	Brief description	Key benefits and co - benefits achieved
China, Wetland reconnection, Hubei Province, China, 2006	The project aimed to reconnect the Zhangdu, Hong and Tian Zhou lakes and their wetlands to the Yangtze River. It was implemented by the WWF - HSBC Yangtze programme. The Yangtze River is the third longest river in the world with basin size of 1,8 million km^2. It has vast wetlands and floodplains able to collect and retain flood water. However, construction of dikes and	– Water environment and resilience. – Natural environment: improved river flow, restored wetlands, storage of excess water in the flood

Case study	Brief description	Key benefits and co - benefits achieved
	embankments prevented development of these natural processes. As a result, over 100 lakes have become disconnected from the river. Sluice gate management was reformed (through their opening) to address flood control issues and native fish species were reintroduced. As a result of the project, an area of 448 km^2 of wetland was restored, providing storage for up to 285 million m^3 of floodwaters.	season and its release during dry season, reduced peak flows; decreased flood risk and restoration of a disconnected and degraded ecosystem.
Wetland restoration, New Forest, UK, 2010	The New Forest Higher Level Stewardship scheme is England's largest environmental improvement scheme aimed at restoration and enhancement of the internationally important habitats of the New Forest in the UK. The scheme covers 20,000 ha and was commenced in 2010. The following aims have been achieved: – Restoration of at least nine miles of drainage channels to natural streams and 150 wetlands – Supporting the historic practice of commoning, which maintains the unique New Forest landscape – Work to identify and protect historic sites across an area the size of 17,000 football pitches, and – Inspiring over 16,500 children to cherish the area's unique environment. The approach to restoration focused on re - establishing meanders, raised beds and installed leaky dams with the aim of slowing flood flows and providing connected habitat.	– Protection of historic environment. – Natural environment (wildlife conservation, enhanced landscape quality and character, resource protection, restoration of watercourses, protection of streams and mires from erosion, improved habitats for rare wildlife). – Human wellbeing (restore wetland for the benefit of the people, promote public access and understanding).

Source: developed by authors using [16]

2.3. Case studies – Restoring Rivers and Catchment Functions

Global urbanisation causes significant degradation of rivers and contributes to decrease of their natural functions. Industrial and agricultural pollution degrade water quality,

increase flooding and the need for water treatment and require more flood control infrastructure. Restoring natural functions provides opportunity for savings (and emissions associated with those activities) along with the creation of recreational space for people and improved biodiversity and habitat connectivity [16].

Activities aimed at restoration of rivers and catchment function involve (i) management of water resources and land use practices on a river catchment scale in order to reduce flood risk, soil erosion, sediment build - up and pollution as well as to enhance flow and habitat, (ii) reinstatement of natural processes (vegetated banks and meanders), (iii) improvement of water quality, ecosystems' health, climate resilience and access (Table 4). The goal is to restore water courses' geomorphological function and to protect and improve water resources for all through utilisation of the nature - based solutions. Naturally functioning rivers help mitigate flooding, deliver freshwater supplies, boost recreation, store carbon and improve health.

Table 4 – Restoration of rivers and catchment functions

Case study	Brief description	Key benefits and co - benefits achieved
Lower Danube green corridor: floodplain restoration for flood protection, 2000 - 2020	In 2000 the Lower Danube Green Corridor Agreement was signed with the aim to establish a 11,500 km^2 green corridor along 1,000 km of the Lower Danube. The Agreement was aimed at the protection and restoration of wetlands along the river and the reconnection of the river to its natural floodplains. The objectives of the Lower Danube Green Corridor Agreement are: – to enhance 735,000 ha of existing wetlands and the creation of 160,000 ha of new protected areas; – to restore 224,000 ha of the natural floodplains; – to promote sustainable use of the area. Actions implemented include (i) removal of dikes to resume natural course, (ii) reconnection with the main river, (iii) clearing invasive vegetation, and (iv) planting native trees. To date, the flood restoration along the Lower Danube is estimated to cost € 183 mln. Expected annual earnings through	– Environmental benefits: improved natural capacity to retain and release flood waters, reduction of flood peaks, increased resilience of the natural systems, reduced flood risk. – Natural environment: enhanced biodiversity (habitat restoration, bird species returned, and fish population increased). – Climate change adaptation and resilience. – Economic and social impact (strengthening local economies through development of fisheries and tourism, diversification of livelihoods based on

Case study	Brief description	Key benefits and co - benefits achieved
	ecosystem services (flood control, water purification, groundwater replenishment, sediment and nutrient retention, reservoirs of biodiversity, recreation, tourism, etc.) from restored floodplains was estimated to be € 111.8 mln per year. Each hectare of restored floodplain is estimated to provide € 500 per year in ecosystem services, helping to diversify the livelihoods of local people [11].	natural resources, lower maintenance costs for local infrastructure).
Emscher restoration generation project, Germany, 1990 – present	The Emscher River restoration project is a large - scale long running project implemented in the former Ruhr coalfield area, Western Germany. This extensive project is aimed at reconversion of the highly modified open wastewater channels into near natural streams and complete clearance from underground sewer pipes installed along the river and the creation of a near - natural landscape. It was envisaged that the project goals could be achieved through construction of a completely new wastewater management and treatment system. Lake Phoenix was created for floodwater storage and recreation; with cycle paths, footpaths, parks, and green space. Floodplains were reconnected and natural wetlands re - established. The project was part of a 28 - year project to restore the entire river basin area of 865 km^2, at a cost of EUR4.5 billion, due to finish in 2020 [16].	– Environmental benefits: improved waste management, improved water quality, increased protection against flooding, improved storm management, restored natural hydrology. – Economic and social impact (sustainable tourism and increase of number of jobs for local population). – Natural environment (increased green space areas, reduced biodiversity loss, restoration of derelict areas).

Source: developed by authors using [11, 16]

2.4. Case studies – Nature - based Solutions for Economic Recovery

Nature - based solutions for economic recovery can provide strong financial and well - being benefits for local communities and nations. Such projects can deliver substantial economic and social benefits for local people and society in general in the form of goods, income (aid economic recovery), employment (creation of new jobs), and overall well -

being. They have been identified as one of the most efficient forms of economic recovery in the wake of COVID - 19, i.e. creation of jobs in tourisms, fisheries, forestry, etc. [5]. Socio - economic benefits brought by NbS can be achieved alongside addressing the intertwined climate change and biodiversity loss crises. NbS could provide valuable economic benefits, some of which are illustrated in Table 5.

Table 5 – Nature - Based Solutions and Economic Benefits

Sector	Nature - Based Solution	Economic Benefits
Mountain, forests and watersheds	Protect, restore and manage forests to store carbon Stabilise, soil and slow water runoffs during intensive rainfalls Sustainable harvesting and community management Plant native trees on degraded and abandoned farmlands	Every dollar invested in restoring degraded forests would return $ 7 - 30 in benefits Protect settlements from floods, slides and avalanches Prevention of financial losses
Rivers and wetlands	Restore wetlands to absorb and filter flood waters, store carbon and provide clean water	Wetland ecosystems provide services worth up to $ 15 trillion, including flood protection, fisheries and water purification
Farmlands	Restore degraded agricultural land to produce more food for more people Sustainable grazing, crop rotation and minimum tillage Shit to sustainable farming with regenerated carbon - rich soils	Reduced GHG emissions Cut energy use during farming Restoring 160 mln ha of land would create $ 84 billion in annual economy benefits globally
Cities	Replacing 'grey' with 'green' infrastructure by expanding green spaces in and around cities Usage of sustainable building materials Lining streets and roofs with trees and bushes	Restoring upland forests and watersheds could save water utilities in the world's 534 largest cities an estimated $ 890 mln each year Protection against flooding, heatwaves and disease Improved wellbeing More efficient use of agricultural lands due to improved agricultural technologies

Sector	Nature - Based Solution	Economic Benefits
Coasts	Protect and restore mangroves, marshes and reefs to buffer coasts from storms Protecting communities and infrastructure from storms and rising sea levels	Protecting and restoring mangroves could create $ 1 trillion in net benefits globally by 2030.

Source: prepared by authors using [8, 12, 22]

2.5. Case studies – Greening Urban and Industrial Areas

NbS could be especially valuable within urban landscapes. Where solutions can offer numerous opportunities to reduce urban heat, improve air and water quality, promote biodiversity, enhance natural habitats and green spaces, reduce surface water flow. Greening urban spaces can include activities from developing green roofs and pocket parks to city scale planning of greenways and sustainable urban drainage systems and brown field locations. For example, green roofs act as a rainwater buffer and an air purifier, as well as help to reduce the ambient temperature and provide temporary storage for water. An accessible green roof is a place for meetings or recreation for a building's occupants.

Among co - benefits from greening urban and industrial areas as one of NbS could be (see also Table 6):

– water resilience (improved water quality and ecological functions, improved flood resilience);

– natural environment (enhanced biodiversity, improved landscape diversity, protect, restore, expand and create natural habitats);

– climate change mitigation (store carbon);

– economic and social development (improved tourism, recreation and employment opportunities);

– human health and wellbeing (reduced exposure to polluting substances, recreational and health benefits).

Table 6 – Greening Urban and Industrial Areas

Case study	Brief description	Key benefits and co - benefits
Urban Protected Areas, Russia	In Moscow, historical Protected Landscapes (e.g. Elk Island) neighbour to residential areas, older industrial sites converted to museum clusters and shopping centres. The total area of the Protected Landscapes in Moscow is 19,700 ha. There are 145 Protected landscapes of various scales in Moscow.	– Natural environment (prevent flooding, promote biodiversity through increase of animal and plant life, clean water and reduce pollution). – Climate change

	Since 2010, new Protected Landscapes have been developed along Moscow rivers and around large lakes and ponds both in Moscow City and in Moscow outskirts (so - called 'New Moscow'). In the New Moscow 50 % is covered by green areas (forests).	(cut emissions and absorb carbon dioxide). – Human health and wellbeing (deliver recreational benefits via access to green space)
Sponge Cities, China	Concept of sponge cities is a new concept used for flood management, strengthening infrastructure and drainage systems. Proposed implementation in China in early 2000. Instead of developing "grey infrastructure" (pipes, dams and channels), sponge cities allow urban areas to absorb water during heavy rainfalls and release accumulated water during droughts.	– Natural environment (prevent flooding, promote biodiversity through increase of animal and plant life, clean water and reduce pollution). – Climate change (cut emissions and absorb carbon dioxide). – Human health and wellbeing (deliver recreational benefits via access to green space).
Sustainable Urban Drainage	Sustainable Urban Drainage systems (SuDS) are widely embedded in modern urban development. Such systems are designed to manage stormwater (slow, store and clean urban runoff before it enters waterbodies), to mimic natural drainage and encourage its infiltration. They generally combine natural elements (retention ponds, detention basins, swales, rain gardens, soakaways, infiltration trenches and tree pits) with permeable surfacing. Among key benefits of SuDS are: – flood risk management; – water quality management; – community benefits – recreation through acting as sports / play areas; – enabling education and development.	– Water environment and resilience (improved water and air quality, improved water security, biodiversity net gain). – Climate change mitigation (store carbon). – Human health and wellbeing (social and community value).
Restoring and greening	For historical mining regions, such the Kuzbass region of Russia, restoration of	– Natural environment (promote

older coal mining areas, Russia	landscapes disturbed by coal mining is a very important issue. In Kuzbass, about 250 mln tonnes of coal are mined, and over a billion tonnes of mine sole (draw rock) is disposed annually. Experts report that ~120 - 150 hectares of land are covered by the draw rock. Since 2002, disturbed lands are restored by greening gob piles (planting conifer trees and using upper soil with local plant species from new coal exploitation sites to cover older gob piles). These practices meet both international [3, 7] and national requirements [21].	biodiversity through increase of plant life and reduce pollution). – Human health and wellbeing (deliver recreational benefits via access to green space).

Source: prepared by authors using [4, 16]

3. The Role of Nature - Based Solutions for Climate Change Adaptation

A report "Adapt Now: A Global Call for Leadership on Climate Resilience" prepared by the Global Commission on Adaptation [2] highlights the benefits of NbS for climate change mitigation and adaption across different landscapes (Table 7) helping to build resilience to the fast - changing climate.

NbS also offer "opportunities for encouraging mainstreaming of environmental targets into sectors in policy, business and practice that might not traditionally consider or value the environment, thereby strengthening the potential for strong sustainability in decision making" [20].

Nature - based solutions start playing an important role in climate change adaptation policies around the world. They are one of key focuses for such climate adaptation policies of many countries. Such solutions can contribute to reduction of the negative effects of climate change on people (and vulnerable communities), natural environment, wellbeing and economy, and through this increase resilience of the global society and local societies to climate change. In a nutshell, nature - based solutions can provide various adaptation benefits and contribute to climate change mitigation and biodiversity conservation.

Table 7 – How Different Nature - Based Solutions Can Work Together across Landscapes to Build Resilience

Sector	Hazard	Solution
Mountain, forests and watersheds	Loss of life and assets due to intense wildfires	Forest management to reduce risk of super fires
	Landslides, soil loss and siltation due intense rainfall	Protect and restore forests to stabilise soils and slow water runoff

Sector	Hazard	Solution
Rivers and wetlands	Asset loss, yield reduction and contamination due to flooding	Restore wetlands to absorb and filter flood waters
	Reduced or intermittent river flow due to drought	Protect and restore forests and watersheds to regulate flow
Farmlands	Crop failures and livestock loss due to drought	Agroforestry to make better use of soil moisture and reduce evaporation
	Asset loss, yield reduction and transport disruption due to flooding	Protect and restore forests to slow water runoff
Cities	Urban flooding due to intense rainfall	Restore watercourses, expand greenspaces and introduce porous surfaces to reduce flood risk
	Heat stress due to urban heat islands	Expand green spaces in and around cities
Coasts	Loss of land, livelihoods and assets due to rising sea levels and coastal erosion	Restore coastal wetlands, including enhance engineered measures
	Loss of life and assets due to storm surges and inundation	Protect and restore mangroves, marshes and reefs to buffer coasts and absorb floodwaters

Source: Global Commission on Adaptation [2]

There are five key recommendations to ensure that nature - based solutions will be able to reduce exposure to various climate risks and to deliver multiple benefits, including climate change adaptation [19]:

1. NbS for climate change adaptation should be integrated with other policy areas, to unlock synergies and avoid adverse effects.
2. Policy support should explicitly recognize the need for a landscape approach involving a diverse portfolio of NbS.
3. NbS should be carefully designed and implemented through a bottom - up and participatory approach involving multiple stakeholders.
4. NbS should be planned to deliver measurable benefits for biodiversity through enhancing the health, diversity and connectivity of ecosystems and their habitats and species.
5. Adaptation policy should set well - defined time - bound objectives and build capacity to effectively monitor NbS outcomes over the long term.

Various NbS could contribute to climate change adaptation and other potential benefits, i.e. protection, restoration, creation or sustainable management of natural or semi - natural woodlands could improve inland flooding and limit erosion, help to reduce effect of heat waves, improve water availability and air quality, contribute to GHG reduction and enhance biodiversity of the local areas. Improvement of urban green infrastructure could be beneficial for inland flooding and reduction of erosion, improve water quantity and air quality, pose a positive impact on livelihoods and increase cultural value of the areas.

Conclusion

Nature - based solutions attempts to adapt an environment and encourage sustainable and resilient improvements to the environment, mitigate climate change while in parallel permitting societal changes and benefits.

NbS offer a chance for innovation and the possibility to deliver long - lasting and tangible benefits across society. Understanding of natural processes and systems lies at the heart of the approach and are essential in achieving the sustainable development goals, addressing the biodiversity crisis and solving the investment gaps in tackling climate change related challenges.

NbS remain relatively novel, presenting significant challenges and unknowns in terms of their (co)design, operation, maintenance and how we organise their implementation.

NbS have strong support among policy makers, NGOs, project developers, consultants and even contractors, and together they could play a significant role in scaling up of investments in NbS. A key consideration in adopting NbS at scale is the introduction of a systems perspective in managing climate related risks. Some examples provided above demonstrate the successful implementation of such approaches.

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