C4T
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Nature-based solutions for sustainable climate adaptation within Cohesion Policy

Authors:
Prof. Dr Erik Andersson, University of Helsinki, Stockholm University and North-West University
Prof. Dr László Pintér, Central European University and International Institute for Sustainable Development
Prof. Dr Stefan Greiving, Technical University Dortmund

Reviewers:
Dr Luis Galiano Bastarrica, DG REGIO
Dr Sander Happaerts, DG REGIO
Florencia Sanchez Acosta, DG REGIO

Editors:
Anna Kronvall, C4T Secretariat
Richard Simpson, C4T Secretariat

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Key messages

Effectively addressing the complex nature of climate risks calls for dynamic planning, adaptive management, and cooperation among diverse stakeholders.

Nature-based solutions (NBS) have the potential to address climate change adaptation and resilience and frequently come with additional benefits, such as enhancing biodiversity, improving human health and well-being, and reducing financial risks.

Adaptation measures should build upon risk assessments considering multidimensional risk scenarios and how the proposed NBS would function under these.

The effectiveness of NBS depends on understanding and integrating various social, ecological, and technological factors. These include spatial arrangements, hybrid infrastructures, institutional frameworks, and individual perceptions, values, and experiences.

Projects involving NBS in their design should clearly describe the context in which they will operate, including institutional settings, stakeholder involvement and needs, integration with built infrastructure, and policy frameworks.

A successful contribution of NBS to adaptation through cohesion policy support requires the consideration of some critical aspects of implementation mechanisms. These include facilitating co-governance and co-management to enhance ownership, adjusting financing to local needs and contexts, and enabling adaptive learning by establishing adequate monitoring and reporting.

Several EU directives provide opportunities for integrating NBS into policy and planning. However, institutional and legal barriers, land use issues, financing gaps, and inadequate monitoring challenge the potential of NBS.

1. Introduction

THEMATIC FOCUS

As climate change continues, it will, at an accelerating pace, change the circumstances and conditions for human activities and well-being. Working with nature offers various ways to deal with these changes (Kabisch et al., 2016; Seddon et al., 2020). Nature-based solutions (NBS) are now high on the EU agenda, as a means for not only climate change adaptation but also to green and revitalise cities, restore degraded land and water bodies, improve human health and well-being, and contribute to biodiversity conservation efforts (European Commission, 2021).

There is a growing literature exploring when and how green and blue infrastructure, ecological engineering, and NBS may contribute to climate adaptation and resilience (Hobbie and Grimm, 2020; Meerow and Newell, 2017). Adaptation to climate risk via NBS reflects the understanding that existing organisational and technological capacities are often inadequate to cope with climate and climate-related emergencies. Investing in novel, more effective, or complementary capacities is needed (EIB, 2023).

Despite much recent attention in research, planning, and implementation, systemic integration of NBS into mainstream policy and subsidy mechanisms related to adaptation is lacking. NBS projects and infrastructure need to be designed to better match future risks and needs, and to pay more attention to NBS longevity and resilience.

NBS need to be more comprehensively integrated into their surrounding landscapes and human societies. This includes resolving issues related to financial mechanisms and legal frameworks to better match the cost and capacities associated with NBS maintenance. Moreover, NBS need to be upscaled to ensure a sufficient impact on climate risks at regional and national levels. Upscaling needs to include warranting operational monitoring and reporting mechanisms of socio-economic and biophysical impacts in connection with targeted investments in NBS. Moving forward on these fronts requires systematic investment strategies involving private and public mechanisms (EIB, 2023).

Cohesion policy funding represents a significant opportunity for scaling up support for developing NBS that address climate-related risks and vulnerabilities, with additional co-benefits in areas such as biodiversity regeneration and conservation. Such scaling would require the integration of targeted, contextually appropriate criteria into cohesion mechanisms that are calibrated to *projected* vulnerability and adaptation profiles that may go beyond the conditions of present baselines. Criteria are largely missing in cohesion policy mechanisms, e.g. the permissibility of cascade funding to broaden and facilitate the involvement of third parties and the coverage of NBS maintenance costs.

This Knowledge Piece summarises the essential knowledge needed to work with NBS to advance adaptation to a rapidly evolving climate risk landscape without losing sight of the many other challenges that NBS could help mitigate or possibly exacerbate. The Knowledge Piece starts by presenting climate change as a "wicked problem" due to its complexity and unpredictability, underscoring the importance of adopting robust adaptive solutions in the face of escalating climate risks.

The Knowledge Piece then discusses the integration of NBS in addressing current and anticipated climate risks, outlining the systemic factors that allow or hinder NBS to deliver on different expectations. These include spatial configurations, hybrid infrastructures, the institutional setting, individual perceptions, values and experiences, and sustainable drainage systems. The Knowledge Piece further provides an overview of how support for NBS to address climate risks and vulnerabilities through adaptation may also produce co-benefits for other prioritised areas and points to some of the main bottlenecks and limitations with current NBS projects. Finally, the Knowledge Piece outlines a strategic approach for NBS projects and presents broadly framed options for support through cohesion policy mechanisms.

MAIN ADRESSEES

The Knowledge Piece is intended for funders/funding authorities, including, but not limited to, regional/national managing authorities, DG REGIO and other relevant European Commission bodies, policymakers, future NBS project members, prospective funding applicants, and beneficiaries.

> **'As climate change continues, it will, at an accelerating pace, change the circumstances and conditions for human activities and well-being. Working with nature offers various ways to deal with these changes.'**

2. Technical background: Working with nature to adapt to a changing climate

2.1 The nature and scale of climate risk, resilience and vulnerability

Climate change is well-established as a wicked problem, i.e. a problem that is complex to solve because solving it requires understanding deeper structural drivers (Meadows, 2008). Such structural drivers are often hidden and manifest their impacts in ways that are hard or impossible to predict with high certainty in terms of location, timing, magnitude, and type of consequences.

'As recent research shows, taking into account future scenarios that also accept the increasing possibility of higher-end climate change is becoming vitally important and may help identify adaptive solutions that are robust across a wider range of futures.'

Nevertheless, the 6th Assessment Report (AR6) of the Intergovernmental Panel on Climate Change (IPCC) notes that at the global level overall, observed adverse impacts of anthropogenic climate change have increased in frequency and severity. It emphasises that human and ecosystem vulnerability are contextual and highly interdependent and that the interplay with unsustainable development patterns may further increase exposure to climate hazards. Further down the line, we are heading towards compounding risks of different types across regions and sectors. As a result, climate change impacts are bound to become more complex and challenging to manage (IPCC, 2021).

Addressing wicked problems runs into all sorts of contradictions. Actors wish for a thorough and nuanced understanding of what is going on and where the process is heading when a full understanding is unachievable due to inherent uncertainties, complexity, and ambiguity (Lazurko et al., 2023). They may require early action with benefits realised in a more distant future when policymaking routines and political interests are predisposed to prioritising the present (Lazarus, 2008). Furthermore, wicked, many-faceted problems may lead actors to compete when cooperation may be necessary to reach more resilient outcomes (Broeke et al., 2019).

'Climate change is well-established as a wicked problem, i.e. a problem that is complex to solve because solving it requires understanding deeper structural drivers.'

Under these conditions, applying traditional decision-making methods, (e.g...) cost-benefit analysis and expected value utility theory, is difficult, as they require exact probabilities and commensurate values (Borgomeo et al., 2018; Dennig, 2018). Instead, there is now a strong support for dynamic planning and adaptive management or co-management. Such approaches aim to identify adaptation policies and processes that respond to new observations over time (Haasnoot et al., 2013; Pahl-Wostl, 2009; Armitage et al., 2009), recognising that active, continuous learning, evaluation and revision are essential for long-term viable solutions (Walker et al., 2013).

Policy design involves monitoring the sequence, timing, and/or threshold values of a set of observed variables relative to critical junctions where decisions need to be made (e.g., after an extreme event or when a new master plan is being developed).

Dynamic planning and adaptive management provide a basis for responding to new observations and situations as they occur. Co-management adds to this the need to engage a broad range of actors in planning, implementation, and monitoring (Olsson et al., 2004) with valid but different interests, knowledge, and capacity that is necessary to navigate the evolving landscape of climate risks and the role of NBS in addressing them.

The recent assessment of vulnerability and adaptation by Working Group II of the IPCC in AR6 paints a picture of complex and increasing climate risks and significant challenges associated with coping and adaptive responses (IPCC, 2023). Impacts are already being observed. They are often significant, and tend to unfold in ways that are highly contextual. Consequently, coping and adaptation mechanisms also need to be rooted in an understanding of the circumstances in a given context. These circumstances may dynamically change over time, combine with, and mutually amplify other non-climatic risk factors.

Given the pace and magnitude of change, calibrating responses to present conditions may be counterproductive. As recent research shows, taking into account future scenarios that also accept the increasing possibility of higher-end climate change is becoming vitally important and may help identify adaptive solutions that are robust across a wider range of futures (Harrison et al., 2019; CRIDF, 2017).

While the international community adopted a framework for Global Goals for Adaptation (GGA) at COP 27 in the Sharm el-Sheikh Implementation Plan, followed by the identification of targets at COP 28, it is also recognised that there is a significant, and in many cases widening, gap between the targets, status and trends (UNEP, 2023). These questions will be covered by the currently ongoing Global Stocktake (GST) mechanisms initiated under the Paris Agreement, which will also investigate the crucial role of adaptive capacity, including climate finance.

2.2 Making nature-based solutions work: dimensions of systemic solutions

Functioning ecosystems, ranging from relatively unaltered by people to highly engineered, have the potential to provide a broad range of ecosystem services (e.g., climate regulation, erosion control, wave attenuation, psychological restoration), many with the potential to help climate adaptation and mitigation efforts (Gómez-Baggethun et al., 2013; Haase et al., 2014; Depietri and McPhearson, 2017).

'Functioning ecosystems, ranging from relatively unaltered by people to highly engineered, have the potential to provide a broad range of ecosystem services.'

However, their functions and services are conditioned by contextual and embedded social, ecological, and technological factors (Andersson et al., 2015; McPhearson et al., 2022). Nature is rarely, in and of itself, providing ready solutions to human problems; it provides a foundation we can build on. Nature-based solutions need to be understood as such – solutions built with nature but with a significant contribution from people.

NBS need to be explicitly recognised in investment criteria to maximise their systemic multifunctionality. This may be done by recognising the interconnections between different types of climate and non-climate risks, the availability of a library of NBS options, and the diverse factors that affect the level and way people can benefit from nature. These may address a complex pattern of adaptation challenges through different pathways. For instance, some elements of sustainable drainage systems (SuDS) may address not only peak runoff associated with storm events but also, e.g., reduce heat stress (tree cover in urban parks), serve as refugia for species at risk (natural vegetation along ditches), or help retain soil moisture during drought periods (permeable pavements) (see the example on p. 9).

'The spatially explicit infrastructure perspective allows one to assess problems with the distribution and accessibility of nature-based solutions and their benefits.'

SPATIAL CONFIGURATIONS

As indicated, individual green or blue elements rarely address the scale or complexity of climate change and vulnerability. Looking instead to green and blue infrastructure (GBI), functionally interconnected systems of different green and blue elements at the landscape level offer a better starting point for finding solutions that can deal with the scale of adaptation needed already in the imminent future (Pauleit et al., 2017). The spatially explicit infrastructure perspective allows one to assess problems with the distribution and accessibility of nature-based solutions and their benefits (Fisher et al., 2009; Haines-Young and Potschin, 2010).

The often-uneven distribution of benefits has clear implications for both the effectiveness of climate adaptation efforts and for aspects of social and environmental justice (Webster, 2007; Reichl, 2016; Haase et al., 2017). The inability to deliver climate adaptation solutions equitably is often discussed in terms of differences in biophysical landscape conditions and urban/regional development pathways (Haase et al., 2017); institutional arrangements, such as property rights and governance schemes (Biernacka and Kronenberg, 2019); current power regimes and procedural justice (Low, 2013); and, closely related to the latter, historical legacies of social inequity and structural racism (Bullard, 1993; Boone et al., 2009).

It is necessary to understand both the basic requirements of the 'solutions' (e.g., types of ecosystems, size, location, relation to the specific climate and climate impact issue, maintenance, among others) and how these interact with the systemic – beyond "green" – setting of the solutions to improve efforts to make better use of the full potential of NBS. Recently, the latter has been conceptualised as a social-ecological-technological system (Wolfram et al., 2016; McPhearson et al., 2021), suggesting a triple framing of nature-based solutions, taking an infrastructural, institutional and people's perspective (Andersson et al., 2021).

HYBRID INFRASTRUCTURES

NBS are embedded in infrastructure networks; the natural or designed and managed spatial systems that provide services to people and are interconnected via flows or transfers of materials, energy, organisms, people, and information. Grey infrastructure and its role in urban risk management and resilience is a vast and well-established field, even if the interest in resilience, and, through it, in more extended time frames and flexibility, is more recent (e.g., Hickford et al. 2018; Linkov et al., 2014). There are also initiatives that address NBS assemblies that form functionally interlinked infrastructure assets as a form of 'naturescape'. However, the unique contributions or opportunities in combining the two are less explored (Whelchel et al., 2018).

Green and grey infrastructure are distinctly different in their life cycles but not incompatible. One central difference is that societal functions of green infrastructure are characterised by regenerative processes, while maintaining the functions of grey infrastructure requires substantial financial investment in continued engineering dealing with material decay. This is not to say that green infrastructure does not require investment in maintenance. However, those investments and institutional capacities (knowledge, skills, equipment, among others) need to be calibrated to the needs of living organisms.

'Comprehensive, large-scale solutions generally include multiple actors in different capacities. Actor roles, rights, and responsibilities are framed by institutions, defined here as a governance system's formal and informal rules.'

The knowledge and resources needed to work with the different infrastructures are often associated with different, commonly disconnected sectors. While these differences pose a challenge, they are also a source of diversity that can be used to build layers of resilience. With the increasing need to build resilience not only to different climate-related disturbances but also to different magnitudes and novel sequences of disturbances, hybrid infrastructures open new avenues for design and bricolage (Andersson et al., 2022).

INSTITUTIONAL DIMENSIONS: LAND-USE RIGHTS AND COLLECTIVELY DEFINED GOALS

Governance and management are essential for the establishment and uninterrupted functioning of NBS. Comprehensive, large-scale solutions generally include multiple actors in different capacities. Actor roles, rights, and responsibilities are framed by institutions, defined here as a governance system's formal and informal rules. These, in turn, need to be understood as situated in a specific socio-cultural, economic, and political context at a certain time (North, 1991; Ostrom, 2009).

'In addition to the spatial jurisdiction of different institutions, studies of the governance system can identify systemic opportunities and constraints for influencing and changing current conditions.'

Together with the physical infrastructures, institutions provide a setting that individuals and groups can use in different ways, pursuing different opportunities and benefits associated with NBS. Institutions may articulate collective or shared values that reflect individuals' roles and perceptions and the norms they adhere to in their social contexts – for example, through political ambitions and priorities (Jacobs, 1997; Vatn, 2005). The institutional context, such as sectoral, jurisdictional, and administrative divisions, is often the basis for problems with NBS management and use (Borgström et al., 2006).

Institutions strongly influence who may or may not benefit, depending on their unique values and challenges. They also actively and continuously shape adaptation in ongoing adaptive co-management, experimentation, and learning processes. Given the right participatory design approach that considers not only human needs but also designing for the 'more than human', they can proactively promote landscapes rich in NBS that maximise their risk reduction potential.

Similar to physical infrastructure, a fragmented policy setting in which sectors (e.g., energy, transport, agriculture, construction, among others) are not aligned in terms of their targets, management strategies, or monitoring and evaluation (Borgström et al., 2006; Stead and Meijers, 2009; Cejudo and Michel, 2017) may reduce the contribution of green and blue infrastructure to human well-being.

In addition to the spatial jurisdiction of different institutions, studies of the governance system can identify systemic opportunities and constraints for influencing and changing current conditions (Allen and Cochrane, 2010; Silver et al., 2010). Recent studies on NBS governance found that managing the generation and flow of benefits requires comprehensive policy mixes involving the combined use of regulatory, financial, and soft instruments (e.g., van der Jagt et al., 2023).

INDIVIDUAL PERCEPTIONS, VALUES, AND EXPERIENCES

Culture, demography, and socio-economic circumstances influence how individuals interpret different environments and circumstances (Stephenson, 2008). For example, being physically active has been highlighted as an important benefit for the elderly engaging in urban gardening (Langemeyer et al., 2018). Although younger people can be assumed to be as physically active while engaging in the same type of gardening activities, they do not place the same emphasis on this as an important benefit (Langemeyer et al., 2018).

Moreover, subjective perception is relevant not only for the individual appreciation of importance and value but also for interpreting the opportunities offered by GBI. Returning to the example of urban gardening, although women in Southern Europe are less likely than men to engage in gardening activities (Camps-Calvet et al., 2016), the opposite has been observed in Northern Europe (Barthel et al., 2010). The example indicates that the individual potential to realise NBS benefits is closely interrelated and shaped by the cultural and institutional context.

In addition to being enabled or hindered by contextual factors, NBS often require multiple complementary green elements to address the different needs that arise, especially during extreme events. These can be considered assemblies of NBS that form dynamic 'naturescapes', configured in terms of biophysical relationships in close proximity, socio-economic processes and impacts, and governance arrangements around specific problems.

Figure 1

Sustainable drainage systems

Sustainable Drainage Systems (SuDS), designed to deal with storm-water and other precipitation-related issues and provide biodiversity and amenity, exemplify what such modular, interconnected systems may entail.
SuDS use combinations of 'natural' or hybrid (green, blue, and grey) elements to manage rainfall close to its source. They are designed to:

- Transport (convey) surface water
- Slow down runoff before it enters watercourses
- Provide areas to store water along natural contours, allowing water to soak (infiltrate) into the ground
- Allow water to be transpired through vegetation (evapotranspiration)

SuDS can include several different components, often hybrid in character, from large to small-scale features, including:

Wetlands: Shallow ponds and reed beds provide attenuation, sediment settlement, storage, and pollutant removal.

Swales: Vegetated drainage channels or troughs with a shallow gradient to reduce flows and provide storage, conveyance of surface water, infiltration and settlement of pollutants.

Trees: Trees can help surface water management through transpiration, interception and filtration.

Permeable pavements: Pavements and hard surfaces that allow infiltration or temporary water storage.

Channels and ditches

Soakaways: Excavated pits provide better infiltration, storm-water attenuation and groundwater recharge.

Rain gardens or filter strips: Vegetated strips that accept runoff provide vegetative filtering, settlement of particulate pollutants, and infiltration.

Green roofs and living walls: Vegetated roofs and walls of buildings that reduce runoff and peak flows.

While systemic multifunctionality can be thought of in physical and ecological terms, the design choices made may also have diverse implications for human use and well-being. Staying with the example of extreme events in a non-climate context, access to nature has been recognised as a significant factor in the ability of urban populations to cope with the consequences of lockdowns during COVID. Human-nature interactions were found to be affected by accessibility, individual capability, and motivation to use nature (Soga et al., 2021). While access to nature can provide immediate benefits such as stress reduction or contribution to food security (Egerer et al., 2022; Levinger et al., 2022), post-COVID studies found that contact with nature increased the motivation of people to be physically active during COVID (Jenkins et al., 2021). Access to and use of NBS may play similarly important roles in climate-related extreme events, mediated by people's perceptions, values, capabilities, and cultural preferences. Access and use should be considered when configuring NBS investments.

'While systemic multifunctionality can be thought of in physical and ecological terms, the design choices made may also have diverse implications for human use and well-being.'

2.3 Bottlenecks, shortcomings and fallacies

INSTITUTIONAL BARRIERS TO NBS IMPLEMENTATION

The implementation of NBS depends on the ways relevant institutions are designed and function. Particularly important are legal issues, especially planning approval procedures, as part of comprehensive land-use planning and/or landscape planning or water management, depending on the specific physical characteristics of the individual NBS. Subsequently, individual project approvals are often a legal requirement. These legal obstacles tend to lengthen the planning phase of NBS and require early coordination with legal entities responsible for approval.

Several connections to EU Framework Directives could be capitalised on for the implementation of NBS, including:

- The Floods Directive (2007/60/EC): "Flood risk management plans may also include the promotion of sustainable land use practices, improvement of water retention as well as the controlled flooding of certain areas in the case of a flood event" (Art. 7 § 3).
- The Water Framework Directive (2000/60/EC): "Measures to ensure that the hydro-morphological conditions of the bodies of water are consistent with the achievement of the required ecological status or good ecological potential for bodies of water designated as artificial or heavily modified" (Art. 11 § 3 i).

In addition, the Environmental Impact Assessment Directive (2014/52/EU, Art.5 § 3 b) and the Strategic Environmental Assessment Directive (2001/41/EC, Art. 5 § 1) offer frameworks for the identification of measures to avoid, reduce and, if possible, remedy significant adverse effects and the environment. These measures may include diverse types of NBS whose implementation and financing are subject to the legal entities or authorities responsible for addressing adverse effects.

The European Commission's proposal for a Nature Restoration Law is the first continent-wide, comprehensive attempt at a law of its kind, published on 22 June 2022 and still awaiting confirmation by the European Council as of April 2024. The law would be a key element of the EU Biodiversity Strategy, calling for binding targets to restore degraded ecosystems, particularly those with the most potential to capture and store carbon and prevent and reduce the impact of natural disasters. The proposal combines an overarching restoration objective for the long-term recovery of nature in EU land and sea areas with binding restoration targets for specific habitats and species.

'The "Nature Restoration Law would be a key element of the EU Biodiversity Strategy, calling for binding targets to restore degraded ecosystems, particularly those with the most potential to capture and store carbon and prevent and reduce the impact of natural disasters.'

These measures should cover at least 30% of EU land and sea areas by 2030 (focusing on Nature 2000 areas) and ultimately 90% of all ecosystems needing restoration by 2050, as adopted by the European Parliament on 27 February 2024. The proposal would have to be adopted by the European Council and published before coming into force.

The implementation of any NBS requires land and/or water bodies. The IPCC confirms that extreme hydro-meteorological events are among climate change's most prominent and urgent consequences and that systemic transformations are needed to tackle such risks (IPCC, 2022). Such systemic transformation requires addressing multiple systems. To transform areas at risk towards systemic climate resilience, working with NBS is widely considered a promising approach (Raska et al., 2022). While NBS are not an entirely new concept, their implementation as systemic measures is still in its infancy in many regions, due mainly to the following reasons:

- Systemic analyses of the cause-effect relations and benefits of NBS are lacking (Raška et al., 2022). While there is growing interest in cause-effect assessments in science (Raymond et al., 2017; Dubovik et al., 2021), they are largely missing in operational NBS planning and decision-making.
- NBS often require more land than grey infrastructure.

Approaches to NBS often focus on public land (Potočki et al., 2022). Private land, however, has enormous potential, both as a supplier (in terms of ecosystem service provision, not least climate adaptation) and as a recipient of NBS benefits (including climate risk mitigation) (Hartmann et al., 2019). The land use system is highly relevant for the transformation toward climate resilience. The importance of land use calls for a focus on land policy instruments (command-and-control, market-based and informational instruments) whose application is strategically important to get landowners on board for implementing NBS.

FINANCING

Climate finance is an essential component of adaptive capacity, and the subtitle of the 2023 Adaptation Gap Report captures the essence of the current situation as "Underfinanced. Underprepared. Inadequate investment and planning on climate adaptation leaves the world exposed" (United Nations Environment Programme 2023). The global financing gap is 10-18 times above present financing for adaptation, more than double previous estimates.

'The consequences of inadequate financing are typically most severe in countries and regions with higher rates of poverty and weaker general adaptive capacity in terms of governance, know-how, and technology.'

The consequences of inadequate financing are typically most severe in countries and regions with higher rates of poverty and weaker general adaptive capacity in terms of governance, know-how, and technology. Financial mechanisms need to support solutions that are failsafe across a wide range of futures at an acceptable cost and capable of delivering multiple benefits without negative social or environmental externalities. Natural infrastructure and NBS generally fit this bill, although they are not yet adequately mainstreamed into adaptation and cohesion finance.

Additionally, contractual and financial issues need to be addressed. Funding schemes for implementing NBS consider various cost categories around their planning, design and implementation. However, long-term maintenance costs of NBS on both public and private land are usually beyond the scope of funding schemes, even though such costs are a significant barrier to the acceptance of NBS by those responsible for maintenance (e.g., local communities, water associations, private landowners). Thus, long-term contractual solutions with time horizons well beyond the typical funding periods of about 3 to 5 years are required.

MONITORING

NBS monitoring is, in most cases, dependent on the respective funding regulations or the willingness and ability of the responsible authority and is very often missing (Almássy, 2022). In the process of NBS realisation, a cross-cutting analysis should, therefore, be undertaken to provide a feedback loop to the applied governance scheme and business models and serve as a monitoring instrument for the NBS implementation. This cross-cutting analysis should consider not only possible immediate biophysical outputs and outcomes but also reflect on the socio-cultural, economic, and governance impacts of the NBS implementation.

Credible monitoring and impact assessment requires significant capacity. Given the wide range of potential impacts arising from the multifunctional nature of NBS, often 'hybridised' with grey infrastructure, monitoring capacity needs to cover a wide range of issues and underlying indicators. Monitoring encompasses quantitative data, including spatial and non-spatial statistical parameters, and qualitative data generated through surveys and other suitable methods to capture both objective and subjective well-being-related impacts.

Besides monitoring past and present trends, the rapid progression of climate change further calls for the projection and interpretation of likely impacts to ensure NBS are scaled to the conditions of future vulnerability. Since mobilising such capacities is often beyond the means of NBS project proponents, funders should consider these when constructing investment programs.

3. Practice recommendations and takeaways

3.1 Risk assessments

While investment programs typically require estimating a wide range of risks with financial implications, they build on historical baselines and probabilities of damage. Given the dynamics and complexity of the poly-crisis, whose driving forces include, but are not limited to, climate change, assumptions reflected in standard risk models may no longer apply. The consequences are becoming well recognised by the climate risk insurance community and reflected in calls for integrated risk reduction and management strategies that NBS can be a part of (Schäfer et al., 2019; Marchal et al., 2019).

Risk assessments need to consider future scenarios that also accept the increasing possibility of higher-end climate change. Scenario thinking helps make structured consideration of uncertainties in climate risks and the multifunctional contribution of NBS to risk reduction or management possible. NBS proposals need to address the often-significant gap between different development targets. These considerations and guidelines will be further developed by the currently ongoing Global Stocktake (GST) mechanisms initiated under the Paris Agreement, which will also investigate the crucial role of adaptive capacity, including climate finance.

'Risk assessments need to consider future scenarios that also accept the increasing possibility of higher-end climate change.'

Risk assessments, including assessing the risk-reduction potential of NBS, should reflect the understanding that risk is not simply a consequence of climate change. Risk is an attribute of complex socio-ecological systems, affected by changes in hazards, exposure to hazards, the type of impacts, and adaptive capacity, among others (Reisinger et al., 2020). Many of these change over time and exhibit uncertainty and ambiguity. Since their manifestation is highly dependent on context, assessments of risk and NBS responses to risk should be contextualised. Consequently, relevant cohesion policy funding programs for adaptation should develop conditionality criteria that require investment plans to address how the proposed NBS would function under multidimensional risk scenarios.

Investment in NBS presents opportunities that go beyond the reduction of climate and climate-related risks. Given their multifunctionality, NBS can be designed to deliver multiple benefits, not all of which may be climate-related. SuDS, for instance, may reduce the risk and damage associated with urban flooding, but they may also enhance biodiversity and urban liveability. Investment in NBS may also be transformative in providing opportunities for restructuring urban space from grey to green or hybrid (grey/green/blue). Including living organisms with needs and lives of their own, NBS requires changes in institutional and individual thinking and behaviour that can contribute to the regeneration of human settlements.

3.2 Project design

Projects need to clearly and explicitly describe the context within which an NBS will work. A project plan needs information about the institutional setting, including information on land ownership, user rights, formal and informal restrictions, stakeholders, and policy frameworks and targets. At the local scale, this may include land-use zonation, special maintenance, and use contracts that promote a narrower range of ecosystem services benefits than the combination of NBS type, ownership, and regulations generally would afford (e.g., by highlighting only a smaller selection of potential uses).

Since NBS introduce more-than-human components into built and human-dominated environments, they also introduce specific physical needs related to their establishment and maintenance (e.g., physical space, nutrient supply, waste processing, temperature, and light regimes, among others). Since these provisions should be guaranteed on an ongoing basis throughout the lifecycle of an NBS, the institutional capacity necessary for their maintenance under projected climate conditions should be considered.

Furthermore, beneficiaries need to be clearly described. Specific needs, knowledge, practices, identities, beliefs, worldviews, literature, and art influence the planning, design, and practical management of NBS, as well as which benefits are desired, realised, and recognised and in what form. Age, gender, ethnicity, and other cultural and socio-economic circumstances may further accentuate these differences.

NBS should be seen as critical infrastructure. Green infrastructure is a good entry point for working with NBS. Green infrastructure is the source and actual basis for NBS, the whole infrastructure system or parts of it. This basis can then be modified to provide a tailor-made solution to specific local climate impacts based on sound evidence produced through integrated climate risk assessment. Individual elements are often insufficient to match the complexity (or scale) of a problem. Therefore, NBS assemblies that form functionally interlinked infrastructure assets as a form of 'naturescape' are needed.

Proponents should also consider how NBS are embedded in built infrastructure since many solutions are hybrid by nature. Projects working with NBS need to recognise and work with regenerative processes, finding opportunities (where appropriate) for substituting engineering solutions and grey infrastructure that require a significant up-front investment in construction and periodic investments to deal with material decay. NBS still need continuous investment, but those investments and institutional capacities (knowledge, skills, equipment, among other) need to be calibrated to the needs of living organisms.

The knowledge and resources needed to work with the different infrastructures, their institutions, and their use are often associated with different, commonly disconnected sectors. Consequently, it is essential to ensure that projects have all the expertise they need.

NBS projects need to present a convincing strategy for realising benefits arising from their multifunctionality, including:

- Clear strategies for navigating trade-offs and promoting synergies, with adaptation priorities in mind.
- A clear definition of target groups and target group needs.
- Mechanisms of engagement.
- Alignment of support through cohesion policy funding with other types of investment.

All benefits are likely to need some sort of continuous human intervention to ensure that they continue to deliver over time, and projects need to clearly demonstrate how this will be ensured.

Figure 2

Key adaptation-related co-benefits of NBS

Biodiversity: The contribution of NBS to biodiversity conservation is not a given. To deliver both biodiversity and adaptation benefits, NBS need to be understood as integrated ecosystem components, not only as single-purpose interventions. They also need to be linked with biophysical conditions at the regional level – aligning with bioregional conditions and using native biological resources strengthens the positive ecological contribution of NBS. Connections with green and blue infrastructure across scales also increase the ecological resilience of NBS. Finally, climate risk and biodiversity needs have different spatial distributions, and not all sites will exhibit them following the same patterns.

Food, water, and energy security: Some NBS intended for climate change adaptation may also support food, water and/or energy security or their various combinations. Community gardens may, for instance, support food security, while depending on their design, may also facilitate groundwater recharge and moderate the urban heat island effect. Roof gardens may improve building energy efficiency while also facilitating local food production. NBS may also address multiple aspects of the same adaptation challenge; for instance, wetlands can potentially help with both water quantity and quality.

(Critical) infrastructure: Critical infrastructure refers to infrastructure that governments consider essential for the reliable functioning of society. While the term is normally associated with grey infrastructure, and there is limited research, there are initial indications that NBS may supplement or even replace grey infrastructure and potentially support its resilience. This may be of particular relevance with regard to disaster prevention and points to "Protective Green Infrastructure," which mitigates negative impacts on critical infrastructure (Sebesvari et al., 2019).

Human health and well-being: NBS may reduce the risk of adverse impacts of climate change on human health during and after extreme events, e.g., by reducing the heat island effect during heat waves or the risk of flash floods during storm events. To justify investment in NBS when there is competition for land, reference to their role in mitigating serious but infrequent disaster risk can be combined with designing them, when possible, for recreation to strengthen social and political support.

Democracy and empowerment: Unlike more 'technical' grey solutions, NBS tend to be more open to non-expert involvement in management and maintenance, which may help configure solutions to different social groups' adaptation needs and capacities. For this to happen, NBS require careful attention also to their institutional design. Dividing and diversifying management rights and responsibilities provides a way to address justice issues and support the perceived multifunctionality of NBS. How to best open up for non-discriminatory participation is a very active and yet comparatively under-researched field.

Financial risk reduction: Climate risks are often associated with considerable financial losses caused by direct damages in exposed areas and indirect losses due to disruption of supply chains and production processes. Compared to grey infrastructure, NBS can be cost-effective adaptation measures with low, non-zero maintenance costs. As NBS are often found on public land and mitigate climate risk that affects entire areas, the benefits of financial risk reduction may be broadly distributed across social classes.

3.3 Project implementation

A successful contribution of NBS to adaptation through cohesion policy support calls for a consideration of some key aspects of implementation mechanisms. These include facilitating participation in governance and co-management to enhance ownership, adjusting financing to local needs and contexts, and enabling adaptive learning by establishing and supporting adequate monitoring and reporting capacity.

CO-PRODUCTION AND ADAPTIVE CO-MANAGEMENT

More systemic NBS often depend on multiple actors, especially if they are to address diverse needs simultaneously. The NBS community has been expanding with multi-agent partnerships that bring together different perspectives, expertise, and experiences from academic, technical, and political fields. These partnerships are characterised by collective and co-creative knowledge production (for more information and guidance, see, e.g. European Commission, 2023) and include a set of critical components that are essential for their successful implementation:

- An iterative process
- Context-specific stakeholder engagement gives a voice to actors often left out
- A unifying framing – targets are broad enough to accommodate different interests
- Guiding principles, inclusive approaches and process designs that encourage stakeholders to utilise their skills and create added value and multiple benefits from the designed NBS
- A clear design for learning-by-doing
- Flexible structure with room for creative and collaborative effort across sectors
- Clear strategies for sustaining efforts in the long term and across changing circumstances

The European Commission has expressed an interest in connecting NBS to the New European Bauhaus, which includes both more attention to the materials and methods used for NBS and an even stronger focus on their social aspects (https://new-european-bauhaus.europa.eu/index_en). Involving multiple actors is a general recommendation, but inclusivity requires careful design and local relevance.

FINANCING

In order to effectively enable adaptation and enhance resilience, financial mechanisms, including cohesion policy funding, need to be at the correct scale and sensitive to needs specific to local contexts. Guided by local stakeholders, they need to be in sync with integrated adaptation plans and goals that consider projected impacts and risks arising from combinations of higher-intensity climate change and other non-climatic forces of change. Furthermore, they need to have built-in monitoring, learning and flexibility mechanisms to respond to unforeseen risks and capacity challenges.

Extensive literature exists on the effectiveness and design of cohesion finance mechanisms. Some general findings are relevant from the NBS and adaptation perspective (Darvas et al., 2019).

- Project duration and foresight: As green or hybrid infrastructure mechanisms, NBS have long development and residence periods, typically multiple decades. Baseline conditions, like climate, may well shift on such time scales, necessitating long-term planning and flexibility during the lifetime of interventions.
- Cross-scale and cross-jurisdiction coordination: While cohesion policy funds are typically tied to national entities, NBS and their effects may extend beyond political borders, as may the impacts of climate change. Cross-jurisdictional cooperation with management authorities in adjoining areas may help create synergies between complementary NBS.
- A balance of centralised control and oversight with locally led problem and solution identification can result in stronger ownership across a wider range of actors and beneficiaries.

'In order to effectively enable adaptation and enhance resilience, financial mechanisms, including cohesion policy funding, need to be at the correct scale and sensitive to needs specific to local contexts.'

- Management authorities need expertise in NBS and adaptation to assist with capacity building, monitoring, and review.

MONITORING AND EVALUATION

Monitoring is a particularly important component of NBS implementation cycles related to adaptation projects, considering the complex and often uncertain match between climate impacts and the complex contribution of NBS to adaptative capacities. However, monitoring is often neglected. This leads to incorrect conclusions, undermining the opportunity for learning and adjustment in case assumptions about the adequacy of adaptation measures.

Monitoring is ideally integrated into adaptation planning with earmarked resources from the start, especially if applicable policies explicitly support it. A monitoring element is, for instance, part of the EU Floods Directive, the EU Water Framework Directive, and the EIA/SEA Directives. Thus, considering the long-term, potentially unforeseen effects of NBS is already guaranteed if the implementation of NBS takes place in the context of a water management plan or as a measure to avoid, reduce, or compensate for adverse effects of plans or projects on the environment.

Monitoring may enable a more effective and ongoing contribution to local adaptation needs and help transfer lessons learned from pilot projects to other locations. Such lessons may be a starting point for upscaling and mainstreaming NBS as an integral adaptation component.

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Cohesions for Transitions (C4T) Community of Practice and the Academic Sounding Board (ASB)

The Knowledge Piece was developed by members of the Academic Sounding Board (ASB) as part of the Cohesion for Transitions (C4T) Community of Practice initiative. The C4T Community of Practice is a **community-based platform that aims to support EU Member States and regions in making better use of EU funds for sustainability transitions**. C4T engages national, regional, and local cohesion and sustainability transitions practitioners in sharing experience and good practices, creating partnerships and jointly identifying solutions. C4T also provides technical assistance to facilitate the development and/or implementation of sustainability transitions.

In the context of C4T, an Academic Sounding Board has been established to serve as **a scientific forum providing advice on sustainability transitions to the C4T Community of Practice and the Just Transition Platform**. It supports the advancement of knowledge related to cohesion for transitions by providing advice for the development of analytical work that is focused on cohesion policy as an enabler of sustainability transitions. Moreover, the board is an important link to the academic community. Science plays a crucial role in making state-of-the-art analytical and academic thinking available. It provides actionable knowledge to Managing Authorities and other public bodies involved in the implementation of funds through research at the intersection of cohesion policy and sustainability transitions. More information on the C4T Community of Practice is available online (https://ec.europa.eu/regional_policy/policy/communities-and-networks/cohesion-4-transition_en)\